IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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SAFETY CONGRESS

Auspices

SAFETY DIVISION

Association of Iron and Steel Electrical Engineers

Wednesday, March 10th, 1926

Thursday, March 11th, 1926

PITTSBURGH, PA.

Safety and the Electric Overhead Traveling Crane

EMPLOYING AND TRAINING CRANE OPERATORS.

A. Physical examination.
B. Mental and physical co-ordination.
C. Course of training and cost of training.
D. Should dependence be placed on strict enforcement of crane rules or men allowed to use own judgment in unusual conditions.
E. Is better service secured by penalizing delays or by personal safety advice?

RULES FOR SAFE CRANE OPERATION

A. Crane operator's rules.
B. Crane director's rules.
C. Signals to be used between Crane Operator and Crane Director.

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A. Ladders.
B. Steps.
C. Walks.
D. Platforms.
E. Gear Guards.
F. Fire hazards in cabs.
G. Switches.
H. Location of switches.
I. Manual or magnetic control.
J. Hoist limit switches.
K. Exposed current carrying parts.
L. Falling crane parts.
M. Failure of ropes.
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RUNWAYS.

A. Signals.
B. Rules for workmen on runways.
C. Approaches to runways.
   A. Ladders.
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   C. Steps.
D. Rail stops.

GENERAL.

A. Rules for protection of workmen on floor.

Safety Directors, Electrical Engineers, Operating Superintendents, Crane and Electrical Manufacturers, Safety Device Manufacturers, are invited to attend.

EDITORIALS

SAFETY AND THE ELECTRIC OVERHEAD TRAVELING CRANE

The Iron and Steel Industry, The State Governments, the Crane Manufacturers, the Electrical Manufacturers, the Manufacturers of Safety Devices, are all combined in the common cause to make the operation of Electric Overhead Traveling Cranes not only safe for the crane operator, but to those workmen whose duties require them to work on crane runways, and last but not least, to the workmen whose occupation is such that it is necessary to handle material over their heads.

Notwithstanding the fact that no money has been spared, that practically every crane has been equipped with every safety device that mankind can devise, that rules and regulations are in force to cover practically every operation a crane may be called upon to perform, accidents still occur.

The price of no accidents is and always will be eternal vigilance, in the form of not only protective devices, but education, which must be supplied by the Safety Directors and their departments with the co-ordination of the heads of the operating departments. If safety is paramount to production more stress and attention must be given to education. Too little attention has been given in the past to the proper training of crane operators. However, the steel companies whom it is agreed are the leaders in protecting the lives of their employees, are taking the necessary steps to properly train the crane operators.

Under the auspices of the Safety Division of the Association of Iron and Steel Electrical Engineers a Safety Congress will be conducted in the month of March at Pittsburgh, Pa The subject to be discussed will be Safety and the Electric Overhead Traveling Crane. The Safety Directors and the Electrical Engineers of the Steel Industry, together with the Crane Manufacturers, Electrical Manufacturers, and the manufacturers of Safety Devices will endeavor, though discussion, to develop a plan of education for the safer operation of the Electric Overhead Traveling Cranes.

ELECTRIC HEAT

It required about 30 years to electrify 65% of the Steel Industry with motor drives. The lessons of the past should provide the way to make the path of electric heat more easily traveled.

The Industry has awakened to the advantages of the electrically heaetd soaking pit. At least five steel companies are planning to install electrically heated pits within the next year.

Electric Heat has solved another problem in the production of quality steel. At the International Nickel Company plant at Huntington, West Virginia, a process beyond the experimental stage has been developed, which might be termed "Electrically Heated Hot Top Ingots."

These ingots are cast somewhat different than the present modern practices in the steel plant, being cast with the large end up, instead of down. In the past it was necessary to cast the ingot with the long head in order to take care of the piping, the head usually weighing on an average of 800 lbs. for small ingot 13x13. After the head was cut off, the ingot weighed about 4,000 lbs. Naturally it was quite an expensive item to saw the heads off, also, the fact that the heads had to be re-handled and re-melted added considerably to the cost per ton.

The idea was conceived of using a single phase arc on the head to keep the metal hot while cooling, which of course would prevent shrinkage. A small portable panel was built using a standard single phase electric furnace regulator for controlling the electrode motor. On the panel was mounted an indicating ammeter, reversing contactors, and a contact making ammeter. The main current busses were run in a compartment along the side of the pouring pit An electrode of about 3" diameter is used. The electrode is placed over the ingot, the arc is then allowed to operate for about two minutes with about two to three thousand amperes passing through the arc. The next three minutes five hundred to a thousand amperes is allowed to pass through the arc.

With this process you are able to secure a solid top ingot eliminating the necessity of cutting off heads and any rehandling and remelting. There are no pipes, the operation is very simple, there is nothing complicated about it. It requires no special apparatus from the electrical manufacturers.

Saturday afternoon, December 12th, in the Blue room the William Penn Hotel, Pittsburgh, Pa., Mr. F. C. Watson, Elec., Engr., International Nickel Co., Huntington, W. Va., will present a paper covering the design and operation of the apparatus used in connection with Electrically Heated Hot Top Ingots.

The Steel Industry is invited to attend this meeting.

THE FUNDAMENTAL PRINCIPLES OF SALESMANSHIP

Engineers as a rule do not make any effort, nor do they devote any time to the art of selling themselves or their profession to their superiors or to the public at large. It might be well for the engineering readers of the Iron and Steel Engineer to read over the following fundamental principles of Salesmanship, and endeavor to co-ordinate the ideas advanced in these principles to some of their every day routine problems.

First Principle: A sale is an exchange of goods or service for money or its equivalent, and the trans-

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*Electricity in the Iron and Steel Industry**

By JOHN C. REED†

"With pen and picture the author, Mr. John C. Reed, has portrayed the present status of electricity in the Iron and Steel industry. Twenty years experiences in the design, installation and operation of electrical apparatus in the Iron and Steel industry qualifies him to present his reflections and opinions. Mr. Reed is a past president of the Association of Iron and Steel Electrical Engineers, and is numbered among those engineers who have generously contributed their talent, energy and time towards the advancement of the application of electricity to the Iron and Steel industry. Starting with the blast furnace department the author presents a very interesting study of how the ore is brought from the mines through the various stages until it becomes molten metal. The description of the open hearth department covers the present modern practices in steel making. Main rolling mill motors and reversing mills, including auxiliary mill drives, are minutely described. Mill tables, roughing mill and finishing mills are gone into at considerable length. Mr. Reed's contribution will be used by the engineers in the industry as an authorative reference for a number of years to come. JOHN F. KELLY.

J. C. Reed

ELECTRICITY in the manufacture of steel and steel products has come into very extensive use during the past twenty-five years. Prior to that time it was used for lighting purposes with a limited application to the operation of motors for line shaft driving and for overhead cranes. Today, there are rolling mills in which the only type of power used is electricity.

Most steel plants generate their own supply of electric current, the source of fuel being the blast furnace gas which is a by-product in the reduction of iron ore to what is usually termed pig iron. This gas is either burned under boilers, thus making steam and using this steam in steam turbines, or else it is used direct in gas engines. Anyone desiring to investigate this phase of the subject is referred to Mr. D. M. Petty's paper on "Power Generation in Steel Plants," published in the 1921 proceedings of the Association of Iron and Steel Electrical Engineers.

Power is usually generated at 6600 volts, 25 cycles, three phase, especially where gas engines are used. Other voltages and frequencies have been used and 60 cycle power is coming more generally into use, owing to the advantages derived from tieing in with the nearby Central Stations which are likely to have 60 Cycle generation. Mr. E. A. Hurme, in his paper entitled "Factors Involved in the Selection of Direct Connected and Geared Main Roll Drives" recently read before the Pittsburgh Section of the Association of Iron and Steel Electrical Engineers, and published in the May issue of the IRON AND STEEL ENGINEER, presents some very interesting statistics relative to the use being made of the two systems.

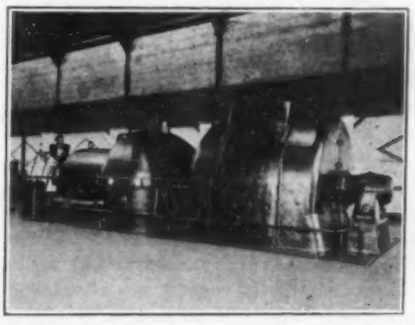

Fig. 1. 10,000 KVA Turbine Inland Steel Co., Indiana Harbor, Ind.

The common practice is to distribute the current at 6600 volts to sub-stations located near centers of distribution. This will usually work out at the point of rolling mill drives. There are a number of systems of distribution but the ring bus system illustrated in Fig. 3 and the radial system illustrated in Fig. 4 are both extensively used. For more detailed informa-

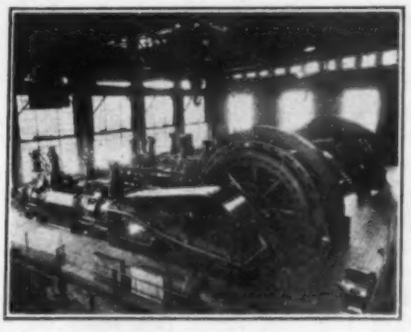

Fig. 2. Gas Electric Station, Steelton, Pa.

*Presented before Philadelphia Section, May 8, 1925.

†Elec. Engr., Bethlehem Steel Co., Steelton, Pa.

tion regarding the ring bus method, see article by Mr. K. M. Raynor, published in the 1922 proceedings of the Association of Iron and Steel Electrical Engineers.

At each sub-station the large motors are operated at line voltage and rotary converters or motor generator sets are used for converting into direct current. If Motor Generator sets are used, the synchronous motors are also usually operated at line voltage. One or more banks of transformers are installed for stepping down to 220 or 440 volts for supplying the smaller induction motors.

responsible in a larger degree than any other factor in producing the present type of ore carrying vessel on the Great Lakes.

The earlier types of Hulett machines were built with a cantilever extension of approximately 160 feet, dumping directly onto the pile. The later types do not have this long extension but dump into a trough along the back wall of the runway and the reloading bridges transfer the material from the trough to the stock pile.

On the Hulett type of machine there is a trolley on which is mounted a beam supported near the

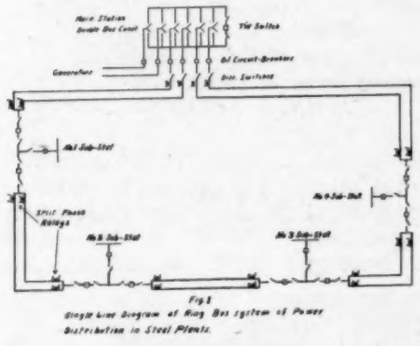

Fig. 3. Ring Bus Transmission System

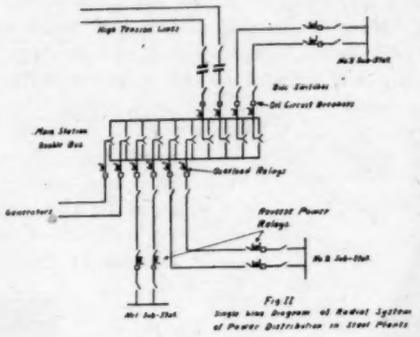

Fig. 4. Radial Bus Transmission System

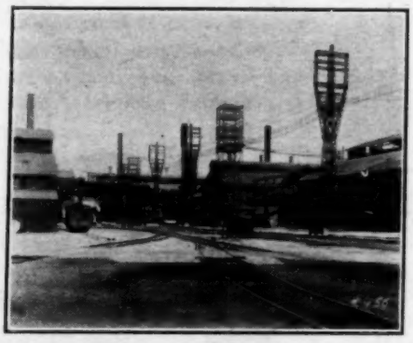

Fig. 5. Transmission Line

Blast Furnace Department

The reduction of iron ore to iron is the first of the metallurgical steps taken in the manufacture of steel. This ore is brought from the mines and unloaded and stored in the ore yard. If the plant is located along the Great Lakes, this ore will come from the Lake Superior region and be shipped to the ore dock in ore boats especially designed for the purpose. These boats have large hatches and a machine known as an ore unloader is used for taking out the ore.

There are two general types of unloaders; one of which is designed solely for unloading and does not

middle on trunnions, the two halves of this beam being set at a slight angle to each other and not in a straight line. At one end of this beam is a vertical mast or leg which is hollow. On the lower end of this leg is mounted the ore bucket which goes down into the hold of the boat, on the other end of the beam is mounted the motor for opening and closing the bucket, the hoist ropes for raising and lowering the bucket leg also being attached to this end.

After the bucket has been filled with ore and is raised vertically out of the vessel, the trolley moves back from the vessel until the bucket is over a car waiting to receive its charge. After the bucket dis-

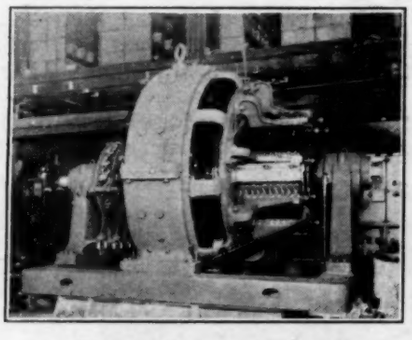

Fig. 6. Rotary Converter

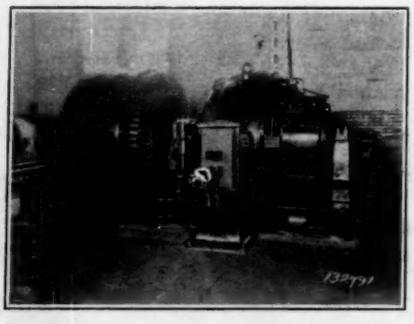

Fig. 7. Motor Generator Set

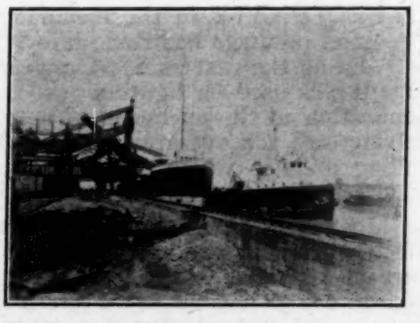

Fig. 8—Ore Unloading Machine, Lackawanna Plant

perform any other function than removing the ore from the vessel. The other type is a combination of ore bridge and unloader, the cycle of operations in removing the ore from the hold of the vessel being the same as removing the ore from a pile.

The best known of the first type is the Hulett unloader, invented by George H. Hulett, and first put into operation at the Conneaut Docks about 1899. The introduction of this type of machine revolutionized the method of ore handling and was directly

charges its load, the trolley moves out over the vessel and the leg is again lowered into the vessel for another load.

The car, in the meantime, has traveled up the inclined extension over the ore pile and deposited its load and returned to its starting point ready to receive the next load from the traveling trolley.

The vertical leg with its bucket can be rotated through 270 degrees either way by a motor mounted on the top of the leg. The rotating of the bucket,

opening and closing of same and hoisting and lowering of leg is controlled by the operator who rides in the leg and has the master switches for the automatic control located in the leg with him. The automatic control boards are mounted in a house on the trolley.

The motors and control for running the ore car and moving the unloader along the docks are located in a house mounted on the lower part of the unloader and do not move with the trolley and are controlled by an operator in this house.

The motor equipment consists of the following:

Operating	No. of Motors	H. P.	Type
Bucket rotate,	1	25	Series D.C.
Trolley,	1	50	Series D.C.
Bucket open and close,	1	75	Straight shunt D. C.
Bridge and car,	2	130 ea.	Compound D. C.
Hoist,	1	275	Compound D.C. 50%
Whirley,	1	50	Series D.C.

The trolley motor drives through a system of gears to pinion meshing into a rack and as the pinion rotates causes the trolley to move in or out, depending on the direction of rotation of the pinion. The hoist motor is mounted on the movable trolley. The bucket opening and closing motor drives through a drum which has a shearing pin. In case

Fig. 9. Ore Unloading Machine, Lackawanna Plant

the operator fails to shut off the motor after the bucket has closed, this pin shears off, relieving the strain on the opening and closing ropes. It might be called a mechanical fuse, as it is a protection to the mechanical end the same as a fuse would be to the electrical end.

The hoist motor is geared to a drum over which are reeved four steel cables, the other ends of which are fastened to the rear end of the movable beam. The weight of the vertical leg on one end of the beam is counter-balanced by the bucket opening and closing mechanism, at the other end also by a massive movable counterweight which travels on a track in the rear end of the beam in such a manner as to counterbalance the leg in whatever position it may happen to be.

On one corner of the unloader structure is mounted a motor operated derrick arrangement called a whirley which is used for hoisting material for making repairs.

Five Hulett unloaders of the older type equipped with 10 ton buckets have unloaded a 12,500 ton boat in less than nine hours, or at the rate of approximately 300 tons per hour per machine. With machines of later design and equipped with 15 ton buckets, records have been made of approximately 400 tons per hour per machine.

The Brown Hoist machine is typical of the combination unloader and reloader and has a span as much as 350 feet over all.

On one end of the bridge is a hinged apron which is held in a vertical position when the machine is used as a reloader, transferring ore from

Fig. 10. Ore Unloading Ore Bridge, Lackawanna Plant

the stock pile to the ore transfer cars on the stock trestle.

When the machine is used as an unloader the apron referred to above is lowered into a horizontal position over the hatches of the boat. This forms a continuation of the track over which the trolley with its bucket travels back and forth. When the trolley is out over the boat, the bucket is lowered through the hatch onto the pile of ore in the hold of the boat and when filled the bucket is hoisted clear of the boat and the trolley moves across the span of the machine and drops the load either on a stock pile or proceeds to the far end and drops it in a transfer car which in turn delivers it to the proper place.

On the later type of machines, each line on the bucket has a 100 H.P. motor controlled independently of any other.

The bucket is a clam shell type having 5 tons capacity. Under favorable conditions, machines of

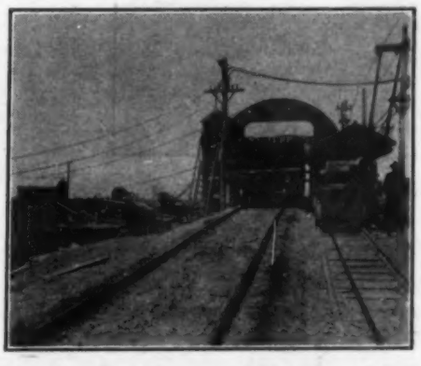

Fig. 11. Car Dumper, Bethlehem Plant

this type can unload at the rate of about 200 tons per hour, per machine.

If the ore arrives at the plant by rail, it must be unloaded by one of two methods. The cars can be spotted over the ore bins or on a trestle along the ore yard and the ore removed from the drops in the

bottom of the cars. This is a slow and tedious process due to the fact that iron ore does not run out like coal or sand, but will stick to the sides of the car so that a great deal of hand work is necessary to get it out of the car. For this reason, most of the steel plants receiving ore by rail use a machine known as a car dumper for unloading the ore.

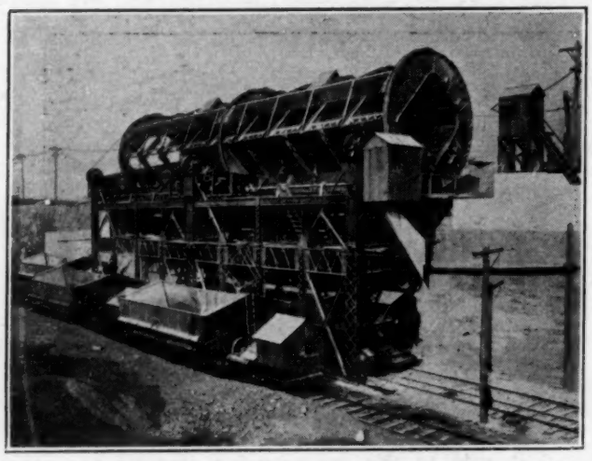

Fig. 12. Car Dumper, Bethlehem Plant

There are different types of dumpers and the kind used will depend upon the general layout of the yard. Some dumpers are portable, that is, they may be moved along the yard on a track and can pick up a car of ore and upset it so that the ore will fall directly into the yard. Others are stationary and dump the ore into a specially designed transfer car from which the ore can easily be removed, and this car is operated up and down on a track along the ore yard.

The cars of loaded ore are drawn up on the dumper by means of a barney car or some type of pusher, after which they are clamped by special devices, motor operated. One of the simplest types of car dumper is the barrel type which consists of a barrel or tube long enough to accommodate two cars. The cars are pushed into the tube and clamped and the tube is then rolled over and the ore slides out of the car into a bin below from which it is removed and placed in the yard by a transfer car. The tracks upon which the barrel rolls, are inclined slightly so that no power is required to return the drum to its normal position. The rolling is accomplished by winding up four steel cables, one at each end and two in the center of the drum. Two 150 H.P. series motors, parallel operated, with a solenoid controller arranged for dynamic braking are used for furnishing power to roll over the drum. Limit switches are provided, which automatically cause the drum to slow down at the proper position. Dumpers of this type can, under favorable conditions, dump thirty-six cars of ore per hour.

Ore Bridge

After the ore has been placed in the ore yard, it is piled up and afterward removed as required by the blast furnaces. The machine for doing this is known as an Ore Bridge. An Ore Bridge is a large gantry crane equipped with a grab bucket.

There are two general types. The stiff legged bridge employed where the span does not exceed 175 feet and the flexible bridge where the spans are 200 feet or more. The stiff legged bridge is constructed similar to a gantry crane, having two motors, one on each side of the girder with cross shafts and bevel gears to transmit the power to the track wheels, half of the wheels being driven. The trolley has also a double motor drive, half of the wheels being driven. The hoist has two motors, one for the hoisting cable and one for the closing cable.

The Electrical equipment on a stiff legged ore bridge having a track span of 167 feet and a 7½ ton bucket is as follows:

Hoist—150 H.P., D.C. Series Motor.
Closing—150 H.P., D. C. Series Motor.
Trolley—Two 50 H.P., D. C. Series Motors.
Bridge—Two 50 H.P., D.C. Series Motors.

These motors are all controlled by solenoid controllers, the hoist controller being equipped with dynamic braking in the lowering direction.

On the flexible type of bridge, the bridge motors are placed down on the trucks, one on each truck, and the controllers are so arranged that, if one end of the crane travels faster than the other end, they are automatically stopped or slowed down until the other end of the crane catches up. This is accomplished by means of a limit switch especially designed for the purpose.

A bridge having a fifteen ton bucket, has the following electrical equipment:

Hoist—Two 150 H.P., D.C. Series Motors.
Closing—Two 150 H.P., D. C. Series Motors.
Trolley—Four 50 H.P., D.C. Series Motors.
Bridge—Four 50 H.P., D.C. Series Motors.

Solenoid controllers similar to those used for the smaller 7½ ton bridge are used. The operator is located in a cage and travels with the trolley.

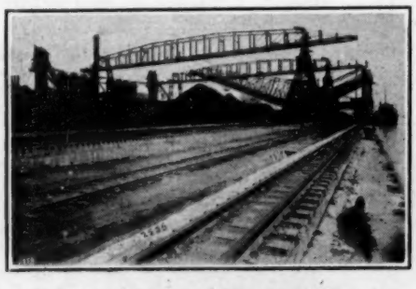

Fig. 13. Ore Bridge, Sparrows Point Plant

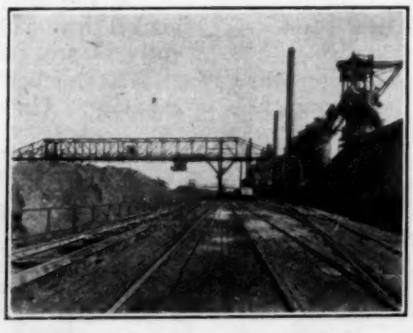

Fig. 14. Ore Bridge, Steelton Plant

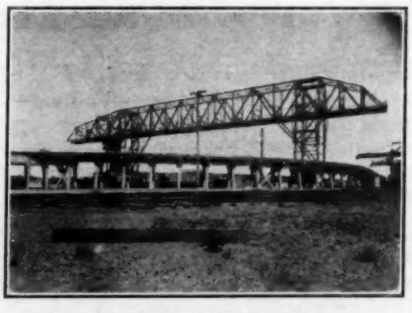

Fig. 15. Ore Bridge, Sparrows Point Plant

Transfer Car

The ore after being placed in the yard is removed as needed by the furnaces, and this is accomplished by the Ore Bridge. It is then placed in an ore transfer car. This car travels on a track located over the ore bins. The car is so designed that the bottom can be opened by means of an air cylinder permitting the ore to drop into the bins. A fifty ton car with which the writer is familiar is equipped with two 60 H.P. series motors arranged for series-parallel operation. The car is geared to travel at 10 miles per hour and in addition to handling the ore can be used for shifting work on the trestle. Air is supplied for operating the drops and brakes by a small motor-driven air compressor similar to those used on the larger street car equipments.

Bins

The stock bins are constructed of reinforced concrete and usually have three or four tracks over them; one track for the transfer car, one for the limestone, one for the coke and sometimes one track for Ore cars where it is desired to drop the ore from cars directly into the bins. The bottom of the bin has a gate or door which is sometimes motor operated. A very common type is to have the bottom of bin closed by means of a drum which, when revolved, causes the material to feed out. These drums are usually started and stopped by means of a clutch which engages them with a shaft which is allowed to revolve all the time.

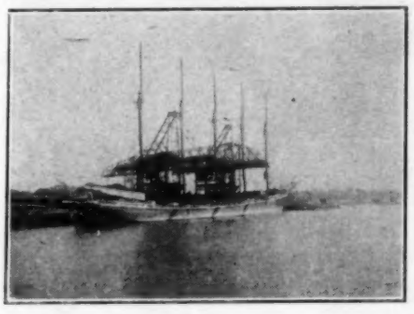

Fig. 16. Ore Bridge, Sparrows Point Plant

Scale Car

The material stored in the bins consists of various kinds of ore, limestone and coke. The scale cars travel on a track under the bins and consist of a hopper car set upon scales which are placed on the car. The material before being put into the furnace is all weighed and a recording device is placed on the car so that a record can be kept of each charge. The scale car takes the material to the skip hoist and drops it into a chute leading into the skip bucket. The electrical equipment on a car which holds ten tons of ore, consists of one 25 H.P. Series street car motor, controlled by an ordinary reversing crane controller.

Skip Hoist

There are a number of different types of apparatus for elevating the ore, limestone and coke to the top of the furnace, but the one most commonly used is the double skip. This consists of a double inclined track upon which rides a car which has a specially designed receptacle or bucket so arranged that when it gets near the top the rear end of the bucket is lifted up allowing the material to slide out into the top of the furnace. A double skip has two buckets, the empty one coming down as the loaded one goes up. The cars are suspended from steel cables wound around a drum which is operated through a suitable reducing gear by a compound 150 H.P., D.C. Motor (A.C. Motors have been used for this purpose). The controller is highly special and of the automatic solenoid type. A limit switch slows down the motor when the car nears the end of its travel and applies dynamic braking when the bucket passes over the hump and automatically stops it at the proper time; an electrically operated brake holds the mechanism when at rest. Fig. 17 shows an elementary wiring diagram of the controller.

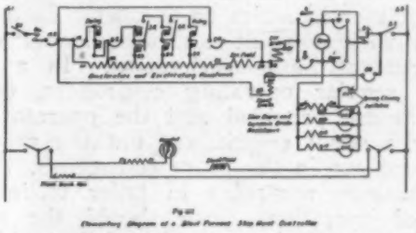

Fig. 17. Simplified Diagram, Skip Hoist Control

Rotating Top

Modern blast furnaces are nearly always equipped with rotating tops for the purpose of assuring an even distribution of the material in the furnace. A 15 H.P. series motor located on the top of the furnace furnishes the power for rotating the top. The cycle of operation is somewhat as follows:

The skip takes up a load of ore which is dumped into the little, or top bell. The bell is dropped and the load falls into the big or lower bell. This is repeated six times, the load being sometimes ore, limestone or coke as the Blast Furnace Superintendent may order. After the seventh bucket is dumped into the little bell, the top rotates 60 degrees before the little bell is dropped and this is repeated six times, after which when the thirteenth load is dumped into the little bell, the bell will rotate 120 degrees which is repeated six times, and likewise after the nineteenth load the bell is rotated 180 degrees six times. After the twenty-fifth load the bell rotates 240 degrees six times and after the thirty-first load the bell rotates 300 degrees for six trips of the skip. The big bell is lowered after the fourth, fifth or sixth skips as may prove to give the best results.

The rotation is entirely automatic and is controlled by specially designed master and limit switches actuated by a ratchet device, solenoid operated. The bells until recently have been dropped by air, but in more recent developments these are also operated electrically and are automatic in their action, the motors being placed below in the skip engine house. The only electrical equipment on top of the furnace is the small 15 H.P. Rotate Motor and a mechanically operated make and break switch used in connection with the rotate control. For more detailed information relative to the working of a blast furnace top I refer you to Mr. F. W. Cramer's paper read before the Pittsburgh Section of the A. I. & S. E. E. and appearing in the June issue of this periodical.

Open Hearth

The molten pig iron is usually hauled in ladles mounted on railway trucks, by means of a standard locomotive from the Blast Furnaces to the Open Hearth where it is emptied from the ladles into a large receiver capable of holding from 800 to 1,000 tons of hot metal. These receivers sit on cradles resting on rollers, and the entire mixer can be tilted so that the hot metal can be poured out of a spout at the top as it is needed. This tilting is accomplished by means of two 75 H.P. Series Mill Motors. These motors are so arranged that they may be operated either in series or parallel. Each motor is equipped with a point control solenoid controller having current limit acceleration. In addition to the two regular operating controllers, two spare controllers are provided and the operator can, by throwing a small switch, cut out the regular controllers and cut in the spare controllers. This is a safety measure necessary in order to insure continuity of operation, since should the mixer be turned down and the controller fail at this critical moment, the operator could not turn the mixer back,

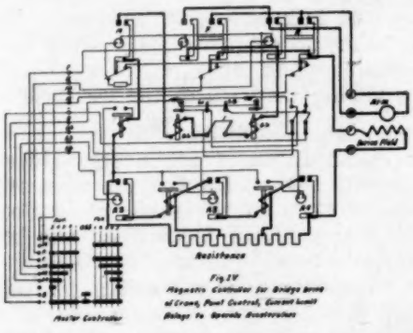

Fig. 18. Magnetic Control Diagram for Bridge Drive

with the result that 100 tons or more of metal, depending on the amount in the mixer and its position at the time, would run out, burning up the scales and the transfer car which are located below the mixer. In order to provide against failure of power, a separate set of lines is run to the Power House and should the power fail, these lines are automatically cut over on a storage battery which is kept charged and ready for service. This battery has sufficient capacity to turn back the mixer a number of times. The controllers used are similar to those used for bridge crane service, diagram for which is shown in Fig. 18.

The metal when poured from the mixer is caught in a ladle of a special design so that it can be lifted by a ladle crane, termed a floor crane. These cranes are usually about 75 tons capacity. Cranes of this type have four girders, for which reason they are sometimes called four girder cranes. There are two trolleys on the crane; the large or main trolley runs on the outside girders and the auxiliary or small trolley runs on the two inside girders. The cables for the main hoist pass down between the two sets of girders on each side to a cross member from which the ladle hooks are suspended. The main hoist of such a crane would be equipped with two 100 H.P. Series Motors. In case of failure, one motor can be cut out and, by overloading the other motor about 50 per cent, the load can be handled. The controllers are of the point control type with current limit acceleration arranged for dynamic braking in the lowering direction. Some engineers use a single controller having double pole switches, one pole being used for each motor. This gives very satisfactory operation so long as nothing fails, but if failure occurs in the control circuits, the entire equipment stops until the trouble is located and repaired. The writer prefers to use two separate controllers operated from the same master switch, but having separate controller fingers for each solenoid controller. The countershaft brakes on the one side being connected in series with the motor brake on the other side, switching arrangements are provided for cutting all of the brakes in series with either motor. Cranes of this type have two cable drums and two sets of cables from each drum, one set of cables being known as the hoisting cables and the other set the safety cables. The two drums are geared together, although more recent and better designs arrange to have the motors geared together. Some trouble has been experienced with the older designs on account of failure of motor on the one side locking one half the crane, in which case the

Fig. 19. Floor Ladle Crane, Steelton Plant

leverage caused by the lowering load and the momentum of the machinery is so great as to break the bolts of the drum bearing caps. The system of inspection and repairs carried out by most Steel Companies is so thorough that accidents caused by failure of ladle cranes are exceedingly rare. The bridge drive on cranes of this type is of the two drive type, one on each side of the crane. Two 60 H.P. Mill motors would probably be used on a 75 ton crane, giving a bridge travel speed of about 300 feet per minute. The main trolley motor would be about 25 H.P. capacity, the auxiliary hoist 15 tons capacity, using a 75 H.P. Motor and the auxiliary trolley motor about 10 H.P.

The metal is carried by the crane to either the Open Hearth Furnaces or to the Bessemer Converters; some mills being laid out so that a transfer car is used for transporting the metal.

Open Hearth Furnaces may be either of the stationary or tilting type. The stationary type have little electrical apparatus connected with them. The doors are operated electrically and those used by the writer are similar to those used on re-heating furnaces, and are described under rolling mills. The throw-over valves which reverse the direction of the gas to the furnace are operated by a 25 H.P. Series motor, operated by solenoid controller. The design of the valve is such that the motor does not reverse, but is stopped automatically by means of a limit

switch at the proper position. The gas regulating valve is operated by means of a 5 H.P. Motor.

The Tilting Furnaces are motor operated and on two hundred ton furnaces, the writer uses four 75 H.P. series motors with a solenoid controller, similar to those used on bridge crane service, one for each motor; all motors operating in parallel. Two sets of master controllers are provided, one master controller which is placed in front of the furnace being the one ordinarily used. A special drum type control circuit double throw emergency switch is placed on the control gallery to be used in case of emergency. This is made necessary on account of the difficulty of always finding a safe route for the control circuit wires leading to the front master. In case of failure of this wiring, the operator runs up on the gallery and throws the emergency switches and operates on the spare master from that position. In case one of the motors burns out or shorts, it will be cut out automatically by the overload relays, and the remaining motors have sufficient capacity to operate the furnace.

In addition to the Open Hearth Furnaces, some plants are equipped with Bessemer Converters for making Bessemer steel or for operating the plant in duplex; that is, iron is first blown in a Bessemer

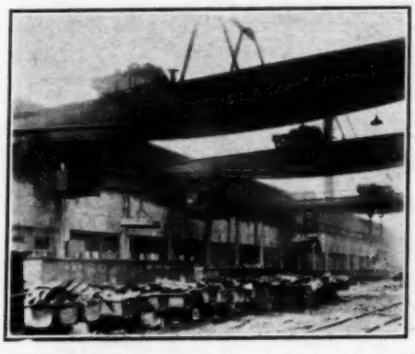

Fig. 20. Magnet Yard Crane, Steelton Plant

converter and then transferred to an Open Hearth furnace. This process greatly increases the capacity of an open hearth plant.

These converters are tilted by two 100 H.P. series motors and the control equipments are similar to that used on the mixers. These motors are operated in series in turning down the vessel while pouring out the heat and in parallel when turning up the vessel; higher speed being desirable for this operation.

In addition to charging hot metal into Open Hearth Furnaces, a great deal of cold steel scrap is used. Scrap is purchased in the market and shipped into the plant and the cars spotted in a receiving yard, usually located back of the charging floor. This yard is covered by a number of light, high speed cranes, five or ten tons capacity. Scrap lifting magnets, fifty or sixty inches in diameter, are suspended from the hooks of the cranes, and the scrap transferred from the freight cars to what are known as charging pans. The latter rest on low steel trucks which may be either broad gauge or narrow gauge. The crane operator rests the magnet on the scrap and turns on the current and immediately starts his hoist; a considerable amount—about 1,000 lbs.—depending upon the kind of scrap being handled, will adhere to the magnet. As soon as the hoist has raised sufficiently, the operator starts his trolley motor and racks out his trolley until it is located over the charging pans, after which he starts to lower and when sufficiently near the pans, opens the magnet circuit, and drops the adhering scrap. These operations, with a skillful operator, are carried out in less time than it takes to tell it. In the plant with which the writer is connected, the cranes are rated at ten tons, but the cables are reaved for

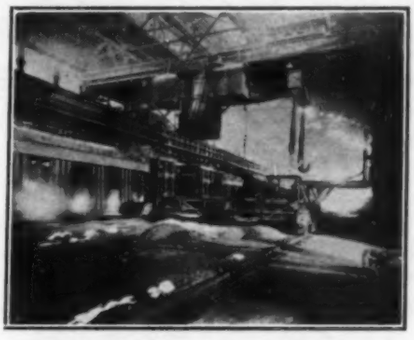

Fig. 21. Charging Machine, Steelton Plant

five ton operation; the hoisting speed being 125 feet per minute, the bridge 400 feet and the trolley 150 feet. The motors used are 60 H.P. on hoist, 50 H.P. on bridge and 15 H.P. on trolley.

The scrap, after being placed on the pans, is shifted into the mill either by a steam locomotive or storage battery locomotive, and placed back of the furnaces. A charging machine especially designed for the operation is used to pick up the pans and put them in the furnace. A rotate is provided for turning the pan upside down. These machines operate on a track set on the charging floor, although there are some types which are suspended. The electrical equipment consists of two 50 H.P. series motors for bridge operation, 50 H.P. series motor on the trolley, a 25 H.P. on the hoist and a 25 H.P. on the rotate. The bridge motors are operated in

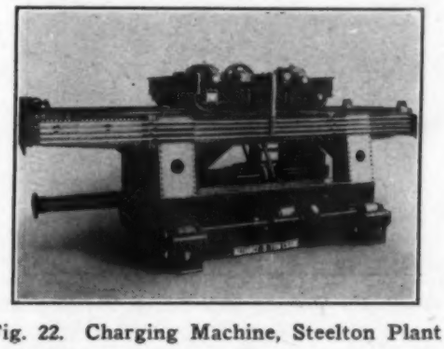

Fig. 22. Charging Machine, Steelton Plant

series in order to provide high torque and low speed for pushing the train of trucks up and down the mill. These machines must be very rugged since they receive probably more abuse than any other machine in a Steel Plant.

The steel is made in the Open Hearth Furnaces and the fuel used is often gas made in a gas producer. This is located near the open hearth and the place generally selected is back of the scrap yard, the gas flues passing under the yard. These gas producers have more or less machinery connected

with them. Induction motors or some other type of constant speed motors are employed for this purpose. These will vary from 10 to 50 H.P., depending upon the type of producers used. Considerable coal handling machinery is used and in the plant with which the writer is connected, a grab bucket crane is employed for this purpose. This is similar in its operation to that of ore bridges previously described. The coal is unloaded from drop bottom cars and elevated by means of the crane and deposited in a

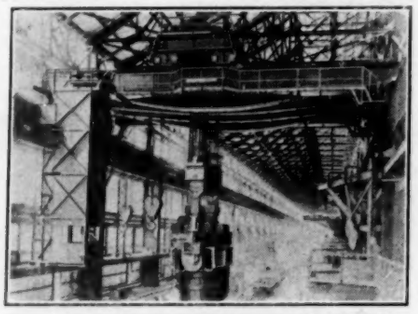

Fig. 23. Ladle Crane, Steelton Plant

traveling coal crusher car where it is crushed and dropped into storage bins. The crusher is operated by a 25 H.P. induction motor.

When the open hearth operation in a titlting furnace is completed, the furnace is tipped and the steel allowed to run into a ladle carried by a ladle crane on the pit side of the furnace. These cranes are in every way similar to the ones used on the floor, except that they are larger; 150 to 200 tons being common. The electrical equipment is the same as used on the floor cranes, the speeds being reduced by additional gears to take care of the heavier loads. The auxiliary trolley has two hoists, one of 40 tons and the other of 10 tons and standard crane equipment is used. These cranes carry the steel to the ingot moulds which rest on cars, after which the steel is

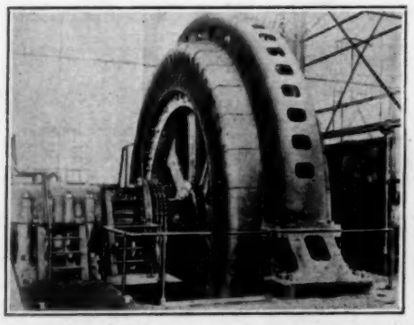

Fig. 24. Main Rolling Mill Drive, Steelton Plant

tapped out of the bottom of the ladle and the crane operator moves the crane from one mould to the next as they are filled.

Rolling Mill Motors

Three high and non-reversing mills are driven by direct connected motors operating at the same speed as the mill, or by higher speed motors in connection with reducing gears, also rope and belt drives on smaller mills have been successfully operated. A fly-wheel is always used in connection with these mills and resistance either permanently installed or automatically inserted in the secondary of the driving motor to increase its slip at heavy loads. This permits the motor to slow down slightly and enables the fly-wheel to give up some of its stored energy and thus reduce the demand on the power plant.

Some mills roll a large variety of products and it is necessary to operate at different speeds and a number of methods of accomplishing this by means of a slip ring induction motor or D.C. motors have been devised. These systems have been very highly developed and operate satisfactorily and efficiently.

Mr. L. A. Umansky, in his very excellent paper presented before the Association of Iron and Steel Electrical Engineers at their convention at Pittsburgh, covered this subject so thoroughly that it will be unnecessary to elaborate on this subject at this time.

Reversing Mills

Reversing mills, which usually are the blooming, roughing and slabbing mills, are driven by means of direct current motors operated from a special fly-wheel motor generator set. A simplified diagram of such a mill is shown in Fig. 26.

A slip ring induction motor is used to operate the generator set and means are provided to vary

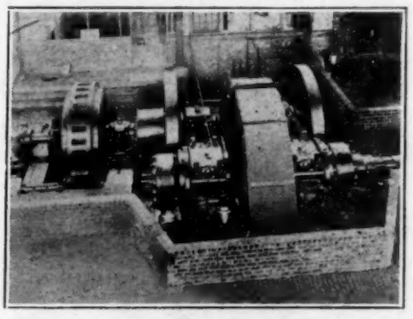

Fig. 25. Geared Mill Drive

the speed of this set so as to permit the fly-wheel to absorb the shocks which would otherwise be transferred to the power plant. The mill motors are reversed by reversing the direction of the field current in the generators. The entire operation is controlled by means of a master switch located in the operating pulpit. This switch simply opens and closes small control circuits which operate the solenoid switches and the controller is protected by means of automatic relays so that it is impossible for the operator to injure the equipment. The operation is as follows: When the operator throws the master switch in the forward direction, a field is built up in the generators which causes the voltage to rise across the generator terminals; these terminals are permanently connected to the motor terminals so the voltage is simultaneously impressed across the motor terminals and causes it to rotate in the desired direction. Increasing the voltage on the generators will cause an increase in the speed of the mill motors up to a certain point; any increase desired beyond this point is accomplished by the operator advancing his master switch still further, which permits certain solenoid switches to close or open, causing a weakening of the motor fields, which permits the motor to still further speed up. When the steel has passed through the mill, the operator reverses his master switch, which reverses the action; the fields of the

motor are first strengthened, which causes the counter electro-motive force of the motors to rise above the voltage generated by the generators, thus causing the motors to momentarily become generators and the generators to become motors. This action is what is usually termed regenerative braking. In other words, the momentum of the revolving mill and driving armatures is converted into electrical energy, which is used to accelerate the speed of the motor generator set, and this energy is stored in the flywheel of the motor generator set. This regenerative braking continues as the voltage dies down on the generators until the voltage is built up in the reverse direction when the motor will either stop, or start to reverse its direction of rotation. All of this takes place in an incredibly short length of time. A 5800 H.P. Continuous rated motor driving a 44" Mill can be reversed from full speed (about 120 R.P.M.) in one direction to full speed in the opposite direction in three seconds.

Mills of this type are exceedingly economical in the consumption of power and will require about 18 K.W. hours per ton in rolling 25"x30" ingots to 8"x8" blooms.

These motors are very ruggedly built and are capable of taking large overloads; for instance the

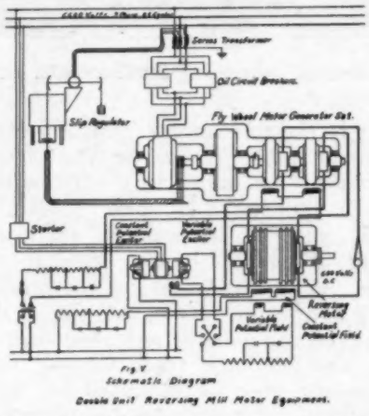

Fig. 26. Schematic Diagram Double Unit Reversing Mill Motor Equipment

5800 H.P. motor, above referred to, will develop a maximum torque of nearly 2,000,000 foot pounds. the peak loads on the power house will not exceed 3200 kilowatts. This is accomplished by means of a liquid slip regulator, which operates by means of a torque motor, which consists of a special induction motor connected in series with the secondary coil of a current transformer. This causes the gap between the plates in the liquid regulator to be increased, thus inserting a resistance in the secondary of the induction motor driving the fly-wheel motor generator set; this causes an increase of slip or a slowing down of the motor, which permits the flywheel to give up some of its stored energy. Some of this is restored again by means of the regenerative current from the motor as previously described.

It is thus seen that the power required to accelerate an electrically driven reversing mill is not wasted, but is returned again in a useful form when the mill is decelerated, and this fact, combined with the other advantages, such as increased production, and decreased cost of maintenance and operation, and general reliability, have caused many mills to be installed in recent years. It is not uncommon for mills of this type to show a power saving equal to 50 per cent per annum of the cost of installation.

It may be of interest to note that in connection with an installation of an electrically driven reversing set on a 44" Mill, a twin tandem condensing reversing engine was torn out and the motor installed and put in operation in twenty-three days.

Auxiliary Mill Drives

There are many special applications of electric motors in connection with special operations used

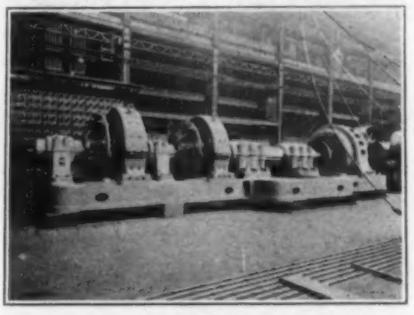

Fig. 27. Flywheel Motor Generator Set

in handling and manipulating the steel in the course of the rolling operation.

The steel is brought from the Open Hearth in cast iron moulds and placed under the stripper runway, where, as soon as the outside steel has solidified, the mould is lifted off. This is accomplished by means of a special type of overhead traveling crane known as a stripper. Ordinarily it is only necessary to lift the mould, which is tapered, off the ingot, but sometimes due to an imperfection on the inner surface of the mould, the ingot sticks to the mould and great force is required to get the ingot loose. This is accomplished by means of a plunger which is mechanically operated, being forced down on top of the ingot. Stripping cranes of this type

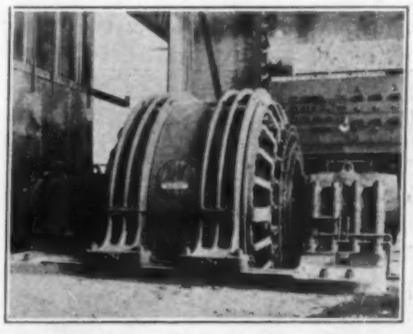

Fig. 28. Reversing Blooming Mill Motor

are usually designed to exert a force of anywhere from 100 to 300 tons pressure. Motors to operate a crane of this type are series wound for 250 volts direct current and would probably consist of the following: Main hoist, 75 H.P., Plunger 75 H.P., Aux. hoist 50 H.P., Trolley 25 H.P., Bridge two 37½ H.P. The controllers for the hoist and plunger motors would be solenoid operated with current limit protection, whereas the other motors would be manually operated. Some engineers use solenoid controllers throughout.

The ingots, after stripping, are transported to the soaking pit building where they are placed in the soaking pits by means of special cranes known as soaking pit cranes. These are stiff legged cranes with a plunger which can be raised and lowered. Upon the end of the plunger are attached dogs which can be opened and closed. The plunger can

Fig. 29. Liquid Slip Regulator

also be rotated, and all of these operations are performed by means of electric motors. A typical electrical equipment on a 20 ton soaking pit crane would as about as follows: Main hoist 75 H.P., Aux. hoist, 50 H.P., Trolley 25 H.P., Dogs 11 H.P., wound for 500 volts, Rotate 11 H.P., wound for 500 volts, Bridge two 37½ H.P. Motors. The controllers for the larger motors are of the solenoid type and the smaller type are for manual operation.

After the ingot is placed in the pits, the covers are closed; these covers being electrically operated, a 15 H.P. motor being about the right size for this

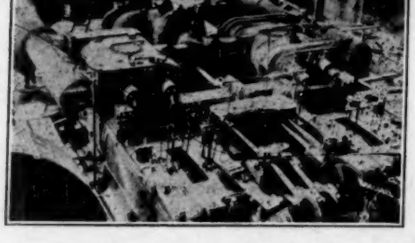

Fig. 30. Reversing Rolling Mill Steam Engine

operation when only one cover is operated by the motor. Sometimes one motor is used to operate a row of pits, in which case a larger motor is used and clutches are thrown in and out to operate the covers.

The pits are gas fired with a non-oxidizing flame, to prevent excessive oxidizing of the surface of the ingot, and the direction of the gas entering the pits is reversed about every twenty minutes. The valve is a highly special piece of apparatus operated by means of a 11 H.P., 500 volt motor, and an automatic controller which starts and stops the motor automatically.

It may be of interest to note that electrically heated soaking pits have been experimented with and the results recently published would seem to indicate that this will probably be the next application to which electricity will be put in the Steel Industry.

After the ingot is properly heated or soaked, which means that the temperature is proper and uniform throughout, the ingot is withdrawn from the pits by means of the same crane used to put

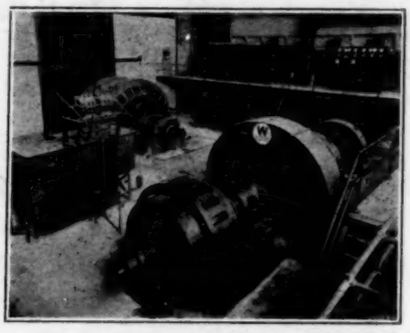

Fig. 31. Electric Reversing Rolling Mill Equipment

them in. It is then necessary to transport the ingot to the approach table leading to the blooming mill. The means used for doing this vary with the general layout of the mill. In some cases the ingot is carried to a chute by the soaking pit crane and allowed to slide down this chute to the approach table in the mills. Where the soaking pit building lies at right angles to the mill table, a transfer car is used. In this case, the car usually is placed on the opposite side of the pits from the track leading to the stripper. The motor may be mounted on the car or it may be operated by means of a cable with a motor

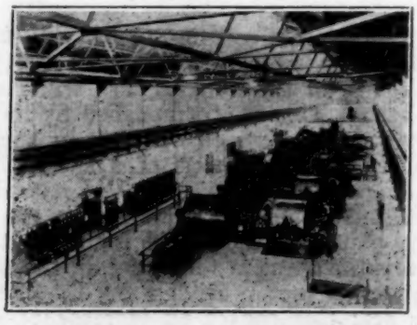

Fig. 32. Power Plant and Rolling Mill Motors

driven crab placed at one end of the track. In either case it is motor operated and controlled by means of an automatic controller which is usually started by the craneman from his cage and automatically stops and tilts when it has reached the spot opposite the end of the roll table. The size of motor used for operating this car will vary with the general design and the speed desired but from 25 to 50 H.P., will usually be found to be the right size.

Roller Tables

After the ingot is placed on the approach table (Table "A," Fig. 38.) it is brought up to the mill tables by means of an electric motor which causes the table rollers to revolve. There are a number of designs of roller tables, but the type most commonly used carries a number of parallel horizontal

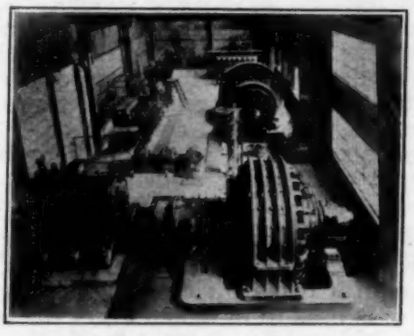

Fig. 33. Rolling Mill Motors

rollers, each having a shaft through the center and supported on bearings at each end. These rollers are driven through bevel gears from an intermediate shaft supported at right angles to the rollers. The proper size of motor to apply to a roller table is difficult to calculate, due to the fact that the co-efficient of friction is such a variable quantity. This is caused by the ever changing conditions as to temperature, lubrication, bearing conditions, alignment, etc., so that in the end it is about as easy to guess at the answer direct as to make a guess at some of the constants entering into a formula to calculate the answer. For this reason mill engineers usually select a motor of ample size which would seem ridiculously large to any one not familiar with steel mill conditions. This frequently results in over-motoring a table which will result in too high speeds if series motors are used and this condition will have to be taken care of either by using compound motors or by automatic devices in the controller. The writer uses a very simple method which consists of a

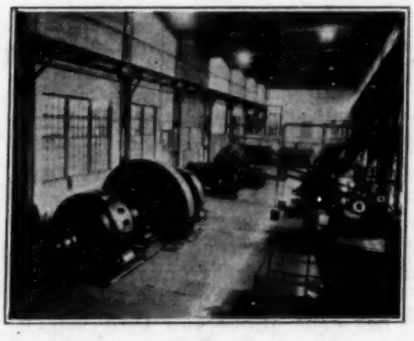

Fig. 34. Rolling Mill Drives

solenoid controller with current lock out accelerator switches. The last accelerator switch, in place of being used to cut out resistance in the motor circuit, is used to place resistance across the armature which will increase the field strength of the motor, thus preventing the motor from obtaining too high a speed. This arrangement permits the over-motoring of a table, using a series motor without any danger that it will ever attain to high speed. Fig. 39 shows a wiring diagram for such a controller.

The ingot after passing over the approach table, rolls on to the mill table which will send it back and forth through the mill.

Note. Anyone wishing to calculate the proper size of motor for roller table drives is referred to

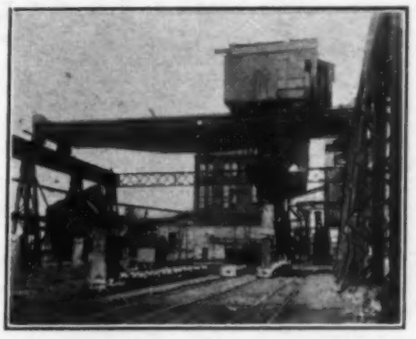

Fig. 35. Hydraulic Stripper Crane

article by Mr. L. A. Umansky, published in the General Electric Review for October and November, 1922.

Mill Table

The mill table carries a number of parallel rollers on each side of the mill, similar to the conveying table above described, except that the rollers are longer and heavier.

There are a number of different methods of handling and connecting up these tables. Some engineers use one large slow speed motor on each side of the mill; others use two or more motors on each side of the mill. The writer prefers to split up the table into four sections, two on each side of the mill and to drive each section with a separate motor. This permits the handling of the ingot with the least possible amount of movement of the table.

The two sections adjacent to the mill, designated "C" and "D" Fig.38, are connected to one master switch and the two outlying sections designated "B" and "E" to another master switch. A simplified diagram of the control circuits is shown in Fig. 40.

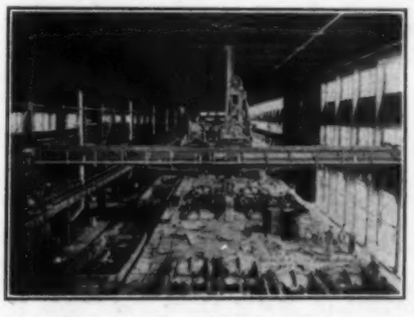

Fig. 36. Soaking Pit Crane

Assuming the ingot to be resting on table "C," the operator moves master No. 2 to forward position designated "F," Fig. 40. This will cause rollers on table "C," Fig. 38 to turn so as to enter the ingot into the mill. After the ingot has passed through the mill, he reverses master No. 2 to the reverse position, designated "R," which causes the rollers on Table "D" to operate in the reverse direc-

tion, causing the ingot to enter the mill from the far side and thus he sends the ingot back and forth through the mill. Should he wish to reverse table "C" so as to bring the ingot back for manipulation, he presses foot switch No. 1, which will cause motor "C" to operate in a reverse direction in place of motor "D." The same foot switch is used in connection with No. 1 Master for operation of motor

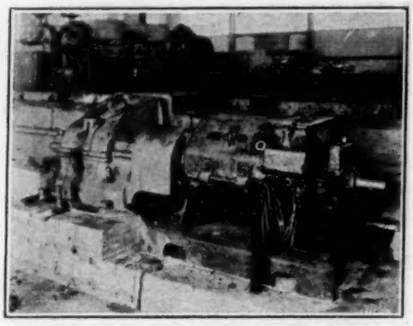

Fig. 37. Mill Type Table Motor

"B" in a reverse direction in place of motor "E." In a similar manner, foot switch No. 2 is used for operating motors "B" and "E" in a forward direction.

In order to move the ingot laterally across the table so as to line it up with the proper pass, it is necessary to have side guards which can be moved. Each guard is operated by two 75 H.P. series mill motors connected in series. The controllers are of the automatic type, having torque limit relays which are so adjusted that whenever the torque reaches a pre-determined point, the accelerating resistance is dropped back into the circuit, thus limiting the torque and protecting the motor, at the same time permitting the motors to stand at rest and exert a pushing effect upon the ingot. Some mills are equipped with slip gears to take up the inertia. These relays automatically open when the current falls. The automatic overload relays rest on the off position of the master controller. Fig. 41 shows a diagram of such a controller.

In addition to moving the ingot back and forth and across the table it is also necessary to turn it

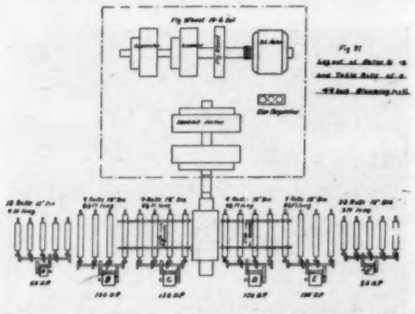

Fig. 38. Layout of Motor Drive and Table Rolls, 44 in. Blooming Mill

over, and this is accomplished by means of machinery operated by two 50 H.P. series motors connected in series. This controller is highly special and entirely automatic in its action. Whenever the operator desires to turn the piece, he runs the finger guard up against the piece and throws the master switch from one side to the other; this will permit the motor to start up, run through a certain cycle of operations and stop; this all has to be accomplished in about a second's time, the motor making six revolutions during the operation. Two motors are used in series so as to furnish as high a starting torque as possible and as little momentum in the revolving part as possible after it has started, so that it can be stopped quickly, this being as essential as the rapid start. In order to stop it quickly, dynamic braking is resorted to, and the switches controlling the dynamic braking circuits are mechanically interlocked with the running switches, the operating coils of the dynamic switches being energized before the limit switch opens the accelerating switches. This causes exceedingly rapid action of the dynamic switches, the ordinary method of using back contacts on the accelerating switches being much too slow for this purpose. Fig. 42 shows the diagram for such a controller.

Another special electrically operated device in connection with two high mills is the screw down. This device is used to raise and lower the top roll of the mill. The roll is balanced by means of a hydraulic balance, so that the motors work against the pressure in lowering the roll and in raising the roll the hydraulic pressure lifts the roll against the

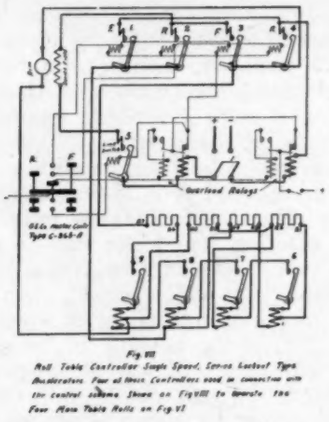

Fig. 39. Diagram Roll Table Controller

screws. Two 100 H.P. Series Mill Motors are connected in series in this operation, for the same reason that two motors are used on the manipulator fingers and side guards. The controllers, however, are plain reversing controllers and the operator plugs the motors through a plugging resistance in order to effect a rapid stop. Screw down service is one of the most severe applications to which motors have been applied. In the first place, the motors are frequently placed on the mill housing directly over the mill so that they receive the direct heat from the steel, and for this reason they are frequently artificially ventilated. The starting current frequently rises to about 100 per cent above full load, which, owing to the fact that the losses in the motor, which are all converted into heat, vary with the square of the current, makes it an exceedingly difficult job. Anyone interested in determining the proper size of motor to use on a screw down, is referred to Mr. Frank Egan's very instructive article published in the July, 1924, number of the Iron and Steel Engineer.

After the steel has been rolled out into a bloom it passes over a conveying table similar to the approach table, to the shear table which is controlled

by the shear operator. There are many different types of shears, most of which are operated hydraulically, the hydraulic pressure being obtained from steam or air intensifiers. The latest development, however, operates the shear direct from an electric motor. A shear capable of shearing an 8 in. by 8 in. or a 10 in. by 10 in. bloom would required a 300 or 400 H.P. motor, preferably direct current, although slip ring induction motors can be used for this purpose. Using a large motor of this type does away with all fly-wheels and clutches, the motor being started and stopped for each stroke of the shear. This can either be put under the control of the operator or a limit switch can be used which will automatically stop the motor after one complete cycle. In case billets or smaller sections are being sheared, the limit switch can be cut out and the motor allowed to continue running, the steel being fed in so that it is sheared at each stroke of the shear.

The descriptions so far have been pretty much common to all steel plants, but from now on there are many variations depending upon what the finished material is to be. Generally speaking, the steel is reheated at this point, although there are products being rolled in continuous mills in which the rolling

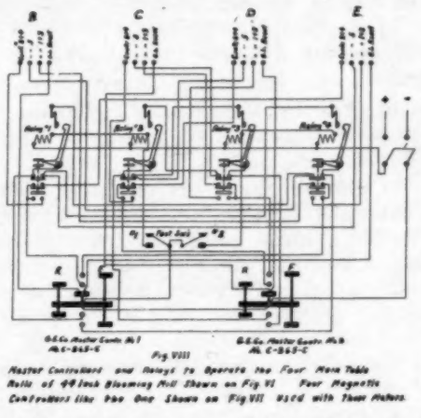

Fig. 40. Diagram Controllers, Main Table Rolls 44 in. Blooming Mill

is so rapid that reheating is unnecessary. Such products as billets, bars, sheet bars, in fact most any rectangular section in which large tonnages are desired can be more economically produced in continuous mills which will take the steel direct from the bloomer and roll it into the finished shape without reheating. Reheating furnaces, however, are generally installed for taking care of cold blooms which it may be desired to reheat and roll. The specifications of the product may also be such that it may be necessary to chip the blooms and thus remove any imperfections in the surface of the product. Rails may be rolled direct from the original heat or may be reheated, some mills do it one way and others do it the other way. The direct rolling saves the cost of reheating, while on the other hand the power required to roll and the percentage of defectives is likely to be increased so that the advantages of the one process about balance those of the other.

If reheating furnaces are used special machinery is necessary for placing the blooms into and removing them from the furnaces and these will depend on the design of the furnace and the general layout of the mill. The mill with which the writer is most familiar has the furnaces set at right angles to the general direction of the mill tables. Transfer cars run along, one on each side of the furnaces. These cars are arranged so that they sink down in depressions of the track at the point where they intercept the conveying table; the bloom is stopped directly over the car and when the car is started it lifts the bloom off of the table and conveys it in

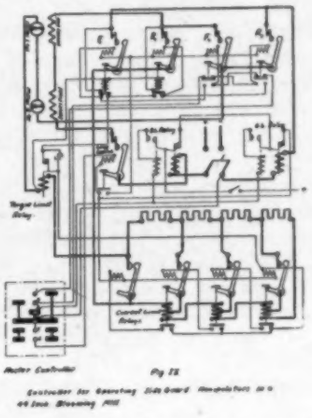

Fig. 41. Diagram Master Controller operating side guard manipulators

front of the furnace where it is picked up by a special type of charging machine. This transfer car is operated by means of a crab placed at the end of the track, a 50 H.P. Compound wound mill motor being used to operate it. The car is operated by the charging machine operator from his cab located on the charging machine. On the return travel, the car, after being started by the operator slows down and stops automatically in the proper position to receive the next bloom. The controller has some of the features common to a skip hoist controller previously described.

The charging machine consists of a special trolley hung from a pair of crane girders and a peel with a pair of dogs which can be opened and closed.

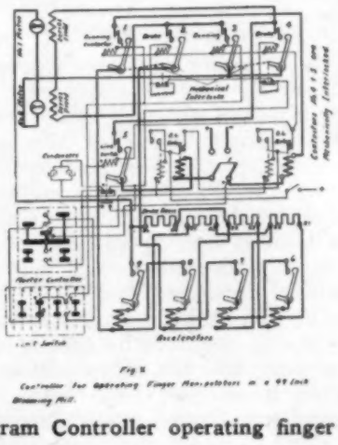

Fig. 42. Diagram Controller operating finger manipulators

The end of the peel can be raised and lowered so that the operator can lower the end, close the dogs, thus pinching the bloom between them, raise the peel and rack forward the trolley placing the bloom in the reheating furnace. He then opens the dogs and racks back the trolley. The electrical equipment on such a machine consists of one 50 H.P. Motor on the bridge, one 15 H.P. Motor on the trolley, one 25

H.P. Motor on the hoist and one 15 H.P. Motor on the grip, all series D.C. Type. The grip mechanism is equipped with a slip gear and a ratchet which prevents the motor from being stalled when the dogs close on the bloom.

There is a similar machine on the opposite side of the furnaces for the purpose of withdrawing the blooms.

The doors on each side of the furnace are operated by means of one horse power, high resistance secondary, squirrel cage, ball bearing, totally enclosed, induction motors. The mechanism consists of a worm and worm gear with a drum having one turn of cable. One end of the cable is attached to the door after passing over suitable sheaves; the other end of the cable has a weight attached to balance the door. The operating switch is a special oil immersed switch so arranged that when the operator removes his hand from the handle, it will go to the off position. The switches are placed along the building back of the charger operator in a convenient position for him to operate the doors. Should he hold the switch too long, the tension is slightly removed from the cable and the cable slips on the

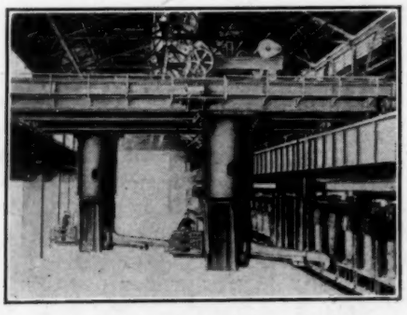

Fig. 43. Reheating Furnace Charger

drum. This seldom occurs and the writer has found that the wear on the cables and drums is a negligible factor. More complicated designs are in common use in some mills.

Roughing Mills

The bloom after being re-heated passes on to the roughing mill which may be either of the two high or three high type. Two high mills are simpler in their mechanical arrangement of the auxiliary devices and are, under certain circumstances, faster than the three high. Two high roughing mills are similar to two high blooming mills except that they are smaller and need not, in all cases, have a screw down. On a 35″ Roughing Mill with which the writer is familiar, there are two tables, one on each side of the mill. The table on the approach side has fifteen rollers and is operated by means of a 150 H.P. Series mill motor; the far table has twelve rollers and is operated by a 100 H.P. Motor of the same type. The side guards and manipulators are similar to those on the blooming mill except that they are smaller. There is no screw down on this mill, the steel progressing from one pass to the next without the necessity of adjusting the space between the rolls. Mills of this type are very fast, which accounts for the large motors used on the tables, these being necessary to obtain rapid acceleration of the table. The controllers used are of the standard table type. The side guards have two 50 H.P. Mill motors operating in series, and the manipulator, one 50 H.P. operating with considerable permanent resistance in series with it. A motor for operating such a mill will have a continuous capacity of from 3000 to 3500 H.P., with a maximum torque of about 900,000 foot pounds.

Finishing Mills

The steel after passing through the roughing mill is sent to the three high mill where it is finished. There are a number of different arrangements of mills, but two stands of three high rolls, driven by a non-reversing motor is one of the most common types. A 28″ Mill will require about a 3500 H.P. Motor running about 90 R.P.M. A large fly-wheel is also used in connection with the mill. The steel is handled by traveling tilting tables, two such tables being placed on each side of the mill. These tables are usually electrically interlocked so that it is not possible for the operator to enter the steel into the mill unless the table on the opposite side is in the proper position to receive it. The electrical equipment on traveling tables will depend on the size, speed and general operation, also another factor, namely the acceleration of the various movements. On a 45 foot table having sixteen rollers, the writer uses a 60 H.P. Mill Motor on the rolls, a 60 H.P. Mill Motor on the lift and two 50 H.P. motors on the bridge.

The steel may be transferred from one stand of rolls to the next either by the tables or by means of transfer placed back of the tables. This consists of a number of parallel racks driven from a cross shaft carrying the rack pinion. A 50 H.P. Series motor equipped with a limit switch is used for operating the racks. After the steel has passed through the final pass it is carried over a number of tables, all motor driven, to the finishing mill which usually consists of one stand of two high rolls, the steel making a single pass through this mill. A 1200 or 1500 H.P. Motor is required to operate the mill. A fly-wheel and reducing gear is interposed between the motor and the mill. The motor used is generally of the slip ring induction type and the controller of the contactor type with oil switches arranged for plugging on the primary, or provision for inserting D.C. current into the primary winding and dissipating the generated current in the secondary resistance. This feature is necessary on account of the fact that the fly-wheel will cause the mill to rotate an hour or so after the current is cut off and some means must be provided to stop it promptly. Unless the work to be done on the final pass is excessive it is usually found that the best operation can be obtained by simply allowing a certain amount of resistance to remain in the secondary circuit. If the work is too great or if there is not sufficient time interval between the pieces then a notching back relay, in case grid resistance is employed, will have to be used or a liquid slip regulator will have to be employed.

Saws, Hot Bed, Etc.

After the steel has been rolled into the desired shape, the crop ends are sawed off and the steel sawed or cut into lengths. In case of rails, this sawing must be very accurately done. There are different arrangements for doing this; some mills are equipped with gang saws which saw, say three

or four rails simultaneously, other mills use only two saws and the front saw removes the front end crop, after which the rail is moved forward against a stop and the back saw cuts the rail to length. The rail is then moved forward against the stop, which has been moved back slightly to take care of the difference in length caused by contraction which has taken place in the time interval between the sawing of the first rail and the sawing of the second rail. The stop must again be moved for the third rail.

Hot saws may be operated by any type of constant speed motor, but on account of their simplicity, squirrel cage induction motors are usually employed. The size of the motor will depend upon the size of the sections to be sawed. Rail mills will require about 75 H.P. motors, while structural mills rolling large sections may require as large as 250 H.P. In addition to the saw motor, the entire saw frame must be slid forward in case of structural saws, in which case a motor with rack and pinion or some other suitable mechanism must be employed. Rail mills usually use tilting saws and the saw is tilted down to engage the rail. Where only two saws are employed as above described, some arrangement must be provided to quickly raise the saw and at the same time to take the rock out of the saw. This is accomplished by placing a counter-weight on the rear end and operating the tilting mechanism by means of a crank. When the motor is started the saw lowers and the weight raises, when the saw has reached the lowest position, the crank pin has reached the highest position and will pass over the center and accelerate the movement; as soon as the saw has reached a position to clear the rail, the current is cut off by a limit switch and the dynamic braking circuit made. This prevents the crank pin from moving past the bottom position, and oscillating back and forth. The writer uses a 11 H.P. 500-volt series motor for this operation.

After the steel has been cut to length it is sent to the hot bed to cool. In the case of rails, it is necessary to curve or "camber" them slightly on account of the head of the rail being at a higher temperature than the base. This is done by means of passing the rails through a set of rolls especially designed for the purpose. This machine is driven by a 75 H.P. Compound Mill Motor. The marking is placed on rails and other sections at this time, and is done by the same machine.

The steel is now passed on to the hot bed, which consists of a large area having a large number of parallel rails set up off the floor upon suitable supports. On each side of this bed are placed roller tables, the one side being known as the receiving side and the other the delivery side. Drags which slide back and forth on suitable guides and operated by means of cables and drums with suitable reducing gear are employed for sliding the rails on the bed. The same type of apparatus may be used for removing them, although there are many designs of machinery for doing this. Series mill motors are employed for doing this work.

The steel, after being cooled and removed to the delivery rolls, is conveyed by this means to the finishing department. In the case of structural shapes they are usually passed through straightening rolls and then are handled by drags or cranes, depending upon the general layout of the plant, to storage yards. In case of rails they must be gagged in order to make them absolutely straight, after which they must be made true at the ends by a small special type of rotary planer, the necessary holes drilled in the ends for splice plates, and sent to the inspecting beds, after which they are loaded by means of overhead cranes and lifting magnets, especially designed for handling rails.

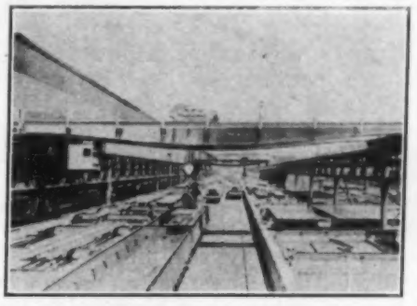

Fig. 44. Rail Loading Crane

In the foregoing description of the rolling process, the writer has adhered pretty close to rail mill and structural mill practice. There are, of course, many different ways of doing things and the general layout of some mills is entirely different from that described, so that it would be impossible to give a description of all methods within the scope of this paper.

Table Controllers

Table controllers in nearly all cases are of the automatic solenoid type and, as previously stated, the tables are usually over-motored and the excess speed at light loads taken care of by special arrangements in the controller or by using a compound wound motor. Another method frequently used is to use two series motors, connecting them in series or using one large, slow-speed motor. Another system which has recently been advocated and which has met with considerable success, is to have a motor on the table of a size more nearly complying with the theoretical requirements and in place of using current limit acceleration, to use a combination of current limit and time limit acceleration. A diagram of such a controller is shown in Fig. 45. This arrangement has the advantage that if the table is tight on account of new bearings or cold weather, the acceleration, while being slower, will still take place without any alteration or resetting of the accelerating relays.

Cranes

Mills in general are covered by electric cranes operating on overhead runways, and these cranes form no small part in the electrical equipment of any steel plant.

For the mechanical specifications the writer would recommend the general crane specifications of the Association of Iron and Steel Electrical Engineers. For determining the size of electrical motors the writer uses the following formula:

For bridge and trolley service H.P. equals $\frac{W \times S}{600}$

in which "W" equals the total weight of machinery and load expressed in tons of 2000 lbs., and "S" equals feet per minute.

$$\text{For hoist service H.P. equals } \frac{W \times S}{11}$$

in which "W" equals weight of load expressed in tons of 2000 lbs., and "S" equals feet per minute.

Very few electrical cranes are fitted with mechanical or load brakes, as was the case some years ago. In place of these, dynamic braking is used for absorbing the energy in lowering the load and a sufficient number of electric brakes are installed for holding the load. The operating coils of these brakes are series wound. The general practice is to place one brake on the motor shaft and one or more brakes on the countershaft. There are many designs of electric brakes such as band brakes, disc brakes, shoe brakes, etc. The shoe brake is the one most commonly used, because of its simplicity. The hoist movement must be protected by means of a limit switch, of which there are many designs on the market, but no matter what design is used, the essential thing is that it cut the motor clear from

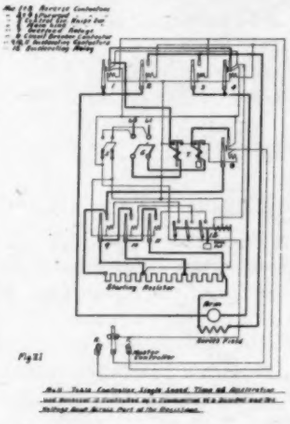

Fig. 45. Diagram Roll Table Controller

the supply of current and cause a dynamic action to take place which will cause the motor to stop quickly. One of the simplest and most effective types is one which is actuated by the hook block and causes a short circuit across the armature. This results in a momentary heavy rush of current through the fields, which trips the overload and because of the heavy field, the armature sets up a high counter electro-motive force, which causes a high short-circuiting current to flow, which in turn stops the rotation instantly. Care must be exercised in setting such a switch, because should the operator turn off the current by means of the controller just an instant before the block reaches the limit switch the dynamic current is greatly reduced and sufficient head room must be allowed to take care of the drift under these conditions.

Modern practice calls for solenoid controllers for all motors in excess of 50 H.P. and where the service is at all severe, solenoid controllers should be used on the smaller sizes. The overload relays can be re-set by means of a push button placed in the cab of the operator, or caused to re-set in the off position of the master controller. Where hand controllers are used, crane protective panels, consisting of a relay for each motor and a solenoid switch, should be used; these being much more reliable than fuses.

There is a difference of opinion as to the necessity of using point control on crane controllers, but this is the writer's preference. Fig. 46 and

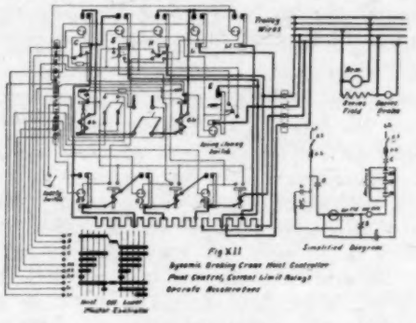

Fig. 46. Diagram Dynamic Braking Hoist Controller

Fig. 18 shows diagrams for point control, hoist and bridge service, using point control with current limit acceleration.

Wiring

The wiring in a steel plant is usually placed in conduit, although there are places where it has been found that open wiring is preferable, such places, however, being rare. The following tables for the size of wire have been found to work satis-

Size of wire to be used on 220-volt D.C. motors.

Size of Motors	Approx. Amperes.	Size of wire, B & S G. Continuous Service	Intermittent Service
3	13	8	8
3½	15	8	8
5	21	8	8
7½	32	6	8
10	42	6	8
15	64	4	6
20	85	2	4
25	106	1	2
30	120	0	2
40	159	00	0
50	199	0000	00
60	239	300,000 C.M.	0000
75	298	300,000 C.M.	0000
100	380	500,000 C.M.	0000
125	475	600,000 C.M.	400,000 C.M.
150	570	800,000 C.M.	500,000 C.M.

Size of wire to be used on 220-volt A.C. motors.

Size of Motors	Approx. Amperes.	Size of wire, B & S G. Continuous Service	Intermittent Service
3	9	8	8
5	14	8	8
7½	20	8	8
10	26	8	8
15	39	6	8
20	39	6	8
25	51	4	6
30	76	2	4
35	93	2	4
40	101	1	4
50	124	0	2
60	148	00	1
70	177	000	0
75	190	0000	00
100	248	300,000 C.M.	000
125	314	400,000 C.M.	0000
150	375	500,000 C.M.	300,000 C.M.

factorily. In these tables no attempt has been made to compensate for voltage drops on long runs. In such cases the regular methods of calculating the size of wire should be worked out and if the size arrived at is larger than that given in the tables, then the larger wire should be used.

In preparing this paper, the writer has only attempted to hit the high spots of electrical engineering as met in the steel plant. In addition, nearly every plant has attached to it a certain number of shops, both for repairs and the manufacture of special lines of products in which they are engaged; also, there are many auxiliary departments, such as by-product coke ovens, quarries, mines, etc., all of which have many special electrical applications.

The Transportation Department has so far not been invaded to any considerable extent, but studies and experimental applications of electric locomotives for shifting service are now being made. Storage battery locomotives have been in use for a considerable time in the Bethlehem plant and the combination gasoline and electric locomotives are now in the market and show promising results.

The writer wishes to acknowledge with thanks, the assistance given him by members of the Association and Electrical and Crane Manufacturers in the preparation of this paper.

*Discussion: Direct Current Armature Windings for Multi-Polor Generators and Motors—Frogleg Windings**

C. S. Proudfoot†: In order to cover all the questions I would like to call on active members first. I would like to have the discussion opened by Mr. Cummins.

A. C. Cummins‡: The first thing I think I should say is that we appreciate very much this discourse, which to me is more like a post-graduate course on the theory of commutation than anything I have ever heard in a meeting of this kind. It takes me back to the days I would be boning at night to prepare for a test in this sort of thing.

Of course, as an executive of this society, it has always been the ambition of its officers to get the sort of paper that really acquaints the membership with something that is new, and that has not been previously described, and which will serve as a medium for their education. I think we are particularly fortunate in having a paper of this character so fully presented this morning. As far as the paper is concerned I will admit there are a good many of the details quite beyond me; however, there are a number of questions I would like to ask Mr. Powell.

I notice there are four layers of coils on the ends of the windings. Now, doesn't that mean that the armature runs hotter than with a standard winding?

W. H. Powell§: If you will refer to Fig. 4, which is a picture of the frogleg coil, you will notice as regards the windings on the back end, there is the same means for ventilation by air spaces between the windings as there are in effect, only two layers as in the standard winding. As regards the front end, there are four layers instead of two and the ventilation by air spaces through the windings is somewhat less. However, with a high-speed machine, the ends are pretty well covered with band wire, and I do not believe there would be much difference in the heating.

A. C. Cummins: Well, in the slots I notice you have four conductors. Isn't it easier to get the heat away from the coils in the slot with the standard armature?

W. H. Powell: As regards the windings in the slots, a portion of the heat is transferred by conduction to the sides of the teeth and then through the teeth to the surface of the core. The core is also cooled by means of vent ducts separating the punchings at close intervals and the coils in the slots also cooled by the air drawn in under the core and expelled at high velocity, past the exposed portion of the coils in the vent ducts. There is no reason to believe that the lower conductor in this type of winding will become any hotter than the lower coil in a two-layer winding provided the same amount of heat is generated in both.

As a matter of fact, however, the four-layer winding actually runs cooler than the two-layer winding as the load losses are much smaller. These load losses are made up of eddy current losses in the conductors and circulating currents caused by unequal magnetic circuits.

If you will refer to the paper, there is given some data which I did not mention in my talk. We built two machines exactly alike as far as frame size was concerned; one with the ordinary winding with a deep conductor and we built another with a winding of the frogleg type, one conductor of one-half the depth of the single conductor. The armatures were of the same dimensions with the same number of slots with the same width of slot, but the slot on the frogleg armature was .2" deeper than on the standard machine, as this extra depth of slot was required for the extra insulation between the coils. These machines were not built at the same time and

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were tested at an interval of probably one year. The first machine was tested at 275 volts and the second was tested at 250 volts. They were 750 KW machines, and were run at 50% overload for two hours and the temperatures taken in the ordinary way. In comparing those machines, after the second one was tested, we found that the frogleg winding actually ran ten degrees cooler. The figures are in the paper. Hence, in answering your question specifically, I would say the machines do not run hotter.

A. C. Cummins: Not only due to the fact that the slots are deeper, but the circulating current is not carried in the ordinary winding in the armature slots but in equalizers—in your winding you have to carry it through the slots and regular conductors, why doesn't it heat?

W. H. Powell: In the first place the slots are only slightly deeper; in fact, one slot was about 1.65" and on the other machine 1.85". Now as regards the circulating current: In the ordinary machines, with cross connectors, the function of the cross-connector is to connect points of equipotential and thus permit circulating currents to flow in the armature conductors if the magnetic circuit is unbalanced. If, therefore, a current is carried in the cross-connector, where does it go? It goes through the armature coil, does it not?

A. C. Cummins: Yes, that is true.

W. H. Powell: In order to be effective at all, the circulating current must flow through the armature coils and the more completely the armature is cross-connected the less the magnitude of the currents in each cross-connector. Now then, the frogleg is, in effect, 100% cross connected, but there are no external cross connectors and hence the magnitude of circulating current in the frogleg coil is reduced to a minimum.

A. C. Cummins: I noticed on the table, that is, the table of performances, where the machine is carrying a greater load at less temperature rise. Does that mean, in substance, that the steel industry is going to be able, in the future, to get a machine for a given duty cycle for less money than we have been able to in the past?

W. H. Powell: I tell you frankly we haven't capitalized on that yet.

We have built slow-speed engine types with cross-connectors and we have built them with a frogleg coil and we have found the commutation was improved and the heating was reduced. We have also built high-speed machines with the same results.

There is one point that I might bring up here that I haven't touched upon before. I refer to the efficiency of a machine. The standard rules of the A. I. E. E. define what is called conventional efficiency. They mean the core loss, windage and friction losses in the armature and bearings, the brush friction, also the copper loss in the armature, interpoles and fields and allow a certain amount for the brush drop. All these losses are what are termed measureable losses except the allowance for brush drop which is arbitrary. Now, they say there are some indeterminable losses which they call "load losses" and which they say should be added to the measurable losses in order to determine the efficiency and they allow for these load losses about one per cent of the full load output.

In comparing two machines exactly alike except the armature windings, if you measure the losses in the ordinary way you obtain the same results for each. The same armature, field and interpole resistance, the same core loss, the same windage and friction, the same brush friction and if you allow the same amount for brush losses and load losses, you arrive at the same efficiency, but when we test this machine we find that the frogleg winding runs cooler. What does that mean? It means we have less of what they term the "load losses" which are, they say, indeterminable. We also find the commutator runs cooler and our armature cores and coils run cooler. We do not have the same amount of energy losses because the losses are transformed into heat and are indicated by temperature rise. So that, when you ask that question as to whether we can capitalize on that—we may some day.

A. C. Cummins: The only thing I had in mind—I believe if labor and material prices were the same today as at the time the non-interpole type was made, the interpole would have meant a lower cost for a machine of given duty.

W. H. Powell: Yes.

A. C. Cummins: And I wondered if this winding would mean a similar improvement.

W. H. Powell: We can make machines running at higher speeds for a given output and generally that means a cheaper machine.

C. S. Proudfoot: I would like to call on Mr. George Schaeffer, President-elect.

Geo. H. Schaeffer*: Mr. Cummins has talked about being back in school. I also have the same feeling, in the same way—only I felt I was listening to the professor and that I had not studied my lessons the night before.

I was very much interested in everything that was said. I am not acquainted with the new type of frogleg winding, but I can remember very plainly, in the short time that we have been using the interpole, what a wonderful stride in the direct current motor this interpole was; and I am inclined to believe the frogleg type of winding will be about as much of an improvement as the interpole was.

I was wondering, however, about the application of this motor to tandem cold rolling, and would ask whether they recommend this motor for tandem or triple hot rolling.

W. H. Powell: I see no reason why such an application should not be entirely successful. When one of our engineers, like Mr. Davis, comes to me and says: "What regulation will you give on these motors?" I reply: "What do you want?" In other words, if you want one-half of one per cent, high or one-half of one per cent low, or ten per cent low or ten per cent high, I say: "All right, go ahead," and I give them what they want. I say: "We will set our brushes and give you what you want." Does that answer your question?

Geo. H. Schaeffer: Yes. In other words, you think it a good thing for cold rolling?

W. H. Powell: Ask some of these men who know the difference between cold rolling and hot rolling. I don't.

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Geo. H. Schaeffer: I was also wondering whether the armature on this machine was more efficient than the armatures we are using today, and he has answered that by stating that the armatures run cooler.

In some of our informal talks among each other we were talking about the old double-circuit armature windings which had been tried, and, I believe, found wanting. I was wondering what the difference is between your frogleg winding and the old double-circuit winding, which didn't divide the current equally.

W. H. Powell: I think I can explain that a little more simply than was explained in the paper. Suppose you have a four-pole machine and we will suppose that it has forty commutator bars. It has forty slots and forty coils, one turn per coil. That would be a very small machine; of course, you would not build a machine that way, but I will speak of it by way of illustration. If you connect the ends of a coil to bars No. 1 and No. 2, you would have ten coils in series between brushes. That would be the standard simplex wound armature. If you connect the ends of coils and bars 1 and 3, you would have only five coils in series between brushes, but would have two parallel circuits. One circuit being bars one, three, five, seven, etc., and the other circuit being bars two, four, six, eight, etc. Perhaps on the blackboard I can explain that a little better.

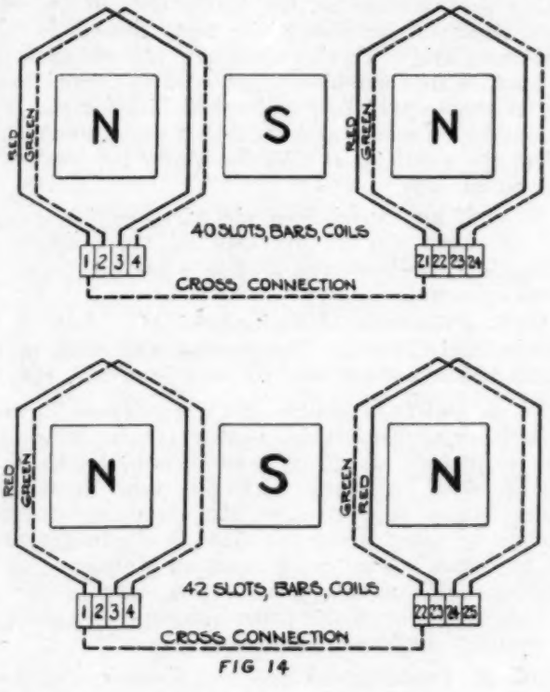

FIG 14

I said, you have forty coils and forty slots. This is a four-pole machine (illustrating on blackboard). Now then, we connect the ends of one coil, one to two and we cross connect one to twenty-one, two to twenty-two, etc. This is a simplex winding. Now, suppose, instead, the ends of the coils are connected to bar one and bar three, and we connect bar two to bar four, we would then have two independent windings, one connected to all the odd bars and the other to all the even bars. In order to distinguish the windings, we will make the odd coils with red chalk and the even coils with green chalk. Now since bar one and bar twenty-one are in symmetrical relation and we cross-connect, you will observe that they are connected from the red coils to the red coils, and if we cross-connect bar two and twenty-two we are cross-connecting from green coils to green coils. Now, these two windings are still entirely independent and are connected in parallel at the brushes only. They are entirely independent windings, that is the old way of doing it and that is the way we have been taught to do it by our text books and that is the way shown by Arnold, the German engineer.

In our duplex interlaced winding, instead of forty slots, bars and coils, we select forty-two; now see the difference. We still connect coil from bar one to three, bar two to four and we still have red coils connected to odd bars and green coils connected to even bars, but our equipotential points instead of being forty divided by two equals twenty, an even number, it is now forty-two divided by two equals twenty-one, an odd number. The equipotential points are now twenty-one bars apart, instead of twenty and our cross connectors connected from a red winding to a green winding. We still have the two independent windings on the armature, but our cross connectors interconnect these two otherwise independent windings. I have illustrated this by use of cross connectors. If we use the frogleg coil we omit the external cross connectors, but we accomplish the same results, and I have illustrated it with cross-connectors, so as to show the inherent difference between the cross-connected ordinary multiple duplex wound armature and the cross-connected interlaced winding. It means this, instead of having those windings independent, they are interconnected by the cross connectors; and instead of having bars one and two on the same potential and three and four on a higher potential, as is the case with the ordinary duplex winding we find in the interlaced winding that bar two, instead of being at the same potential as bar one, is at a potential midway between bars one and three. Take the case that is mentioned in the paper, the armature with a quadruplex winding. We have actually measured the volts between the bars on this machine and the maximum value between bars one and five, which is the volts generated by one coil was thirty-two volts. We measured the volts between two and three, three and four, four and five and so on, and they are approximately eight volts apiece as near as we can measure, the highest being eight and one-quarter and the lowest being seven and three-quarters. That is the difference between the interlaced winding I am describing in the paper and the ordinary double armature winding.

A Member: That story about cutting out a few field coils is very interesting to me. I had considerable trouble when a few fields went bad.

Now, it might be out of order to ask that question, but did you ever think of applying this to synchronous motors; and, if so, could you drop a field or two in synchronous motors?

W. H. Powell: I am not an alternating current motor designer, so I cannot answer that question.

A Member: One other question: As to the division of the current per brush stud. You said you cut

out one of the fields, and you got equal commutation. You changed the current per brush stud, didn't you? In other words, isn't the current per brush stud the same for the different kinds of windings?

W. H. Powell: Yes, it is supposed to be. The current per brush stud is the total amount of current—if they divide equally—the total amount of current divided by the number of positive brush studs. Each is supposed to take its share of the current.

Answering your question specifically—if you cut out the pole—whether that made any difference in the amount of current per stud, there is no means of measuring, and so far as commutation is concerned, no single set of brushes showed signs of distress. So, it is to be inferred they divided as equally as before.

C. S. Proudfoot: We would like to hear from Mr. Shoemaker.

R. S. Shoemaker*: I have been thinking somewhat of the practical side of this motor. What are you going to do on Sunday morning, when we have to put in some new coils? Isn't this type of winding going to be very much harder to repair? If you have double coil span and you have to put in several coils, what are you going to have to do—tear it all apart?

W. H. Powell: It means, as we showed in our picture, you have got to lift the coils from the two coil spans. In that respect, if the damage is due to one armature coil, it does take a little longer to repair it; but if your armature is cross connected on the back end—as lots of the large ones are at the present time—you have got to unsolder all those joints. We have no joints there. As far as repairing the one coil is concerned, it will take a little longer. As far as the repair of the whole armature is concerned, I don't think it will be any longer. We have found that very often the trouble is in the cross-connectors.

R. S. Shoemaker: One thing I had in mind—if the coils crack?

W. H. Powell: Our coils are completely insulated with no soldered joints except at the commutator neck and though it takes a little longer to install them, but we see no reason in the world why these coils should crack any more than the ordinary coil, as they do not have to be distorted in placing them in position. The workmen who put in the coils find they go in nearly as easy as the other coils. Our coils are completely insulated, receiving several coats of baking varnish before they are placed on the armature and we have experienced no trouble which might be caused by cracking the insulation when the coils are installed on the armature.

R. S. Shoemaker: One other point: Just what do you mean by "black commutation?"

W. H. Powell: Black commutation? I think I have a copy of the Institute rules here. I will read you what they say about commutation—Standard Rules of the American Institute of Electrical Engineers define commutation as follows:

"Successful commutation defined. Successful commutation is attained when neither brushes nor commutator are burned nor injured in an acceptance test, or in normal service to the extent that abnormal maintenance is required."

I don't know what they mean by "abnormal maintenance"—whether, for example, if you have to stone your commutator once a week and sand in the brushes, that would not be considered abnormal maintenance and hence commutation would be called successful. The rest of the paragraph is as follows:

"The presence of some visible sparking is not necessarily evidence of unsuccessful commutation."

If there is present certain visible sparking, which we call pin sparking, and which does not do much damage, according to this rule, the commutation is successful.

Now, what do we mean by black commutation? Perhaps I can answer that best by relating an incident that occurred when the test mentioned in the paper was run off. Some of you engineers were present—and I think the man who made the remark is present today. In this test we short-circuited the field coils of one pole and lifted some brushes, and then there seemed to be an apparent delay in getting the machine on the load. One of the engineers who was watching the test, turned to Mr. Davis and said: "Davis, when are you going to get the load on that machine?" Mr. Davis turned to the man at the switchboard and asked him for the reading on the ammeter and then he turned around and said to the gentleman: "We have fifty per cent overload on already."

Now, if an experienced electrical engineer could not tell there was an overload on the machine by looking on the brushes—that is what we mean by "black commutation."

C. S. Proudfoot: I understand Mr. Hall, of the Illinois Steel Company, has a number of these motors in use and we would like to hear from Mr. Hall.

W. S. Hall*: "I believe the chairman of the meeting has been misinformed, as there are at the present time no motors operating at the South Works of the Illinois Steel Company with this type of winding. I was somewhat amused at Mr. Cummins' question, wherein he asked if our machines in the future would not cost less money on account of simplicity in the winding. He appears to have lost sight of the fact that the decrease of the manufacturers' cost does not necessarily decrease the selling price."

C. S. Proudfoot: I see Mr. Cramer, the Secretary, has a number of questions written down.

F. W. Cramer†: I really don't have many questions to ask. This is about a year too soon, as far as I am concerned. We will probably have about the largest installation of these motors in the country when we install five synchronous motors in sub-station, each driving two one-thousand KW generators; and four mills with three motors on each mill, of fifteen hundred horsepower each. One mill has been rolling light for ten days, but won't roll steel for a week. So we have no data comparing any of the motors or generators yet—having been running them light. There is one question that has been asked me, and I am transferring it to Mr. Powell: Between the two

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layers of coils you have a higher voltage than in the normally wound machine; and, as a result, you have to insulate. Well, the question was, how do you take care of that condition?

W. H. Powell: We have in this coil here (showing a sample frogleg armature coil) a series coil and a multiple coil. There is full difference of potential between these two coils. If the ends of the lap coil are under the positive brush, the ends of the wave coil would be under the negative brush. Take the case of the ordinary lap winding; you have the full difference of potential between the upper and lower coils in the same slot and that is taken care of by the insulation on each coil We insulate these two coils separately for the full difference of potential and we can wind them on the armature as separate coils or tie them together, as is done here, and they will go into the slot as one unit. There is full difference of potential between the adjoining sides of the two coils and each coil is insulated for same. All that means is that the slot must be slightly deeper if we use the same amount of copper (illustrating with sample frogleg coil).

C. S. Proudfoot: Now, we would like to open the meeting for general discussion, and we would be glad to hear from Mr. Hall of the Westinghouse Company.

D. Hall*: Mr. Powell and I are old friends. We were connected with the same company for a number of years, back in 1900. Seventeen years ago I became connected with the Westinghouse Company, and since then I have been interested in developing machines along the lines we have been discussing. Mr. Powell will not let me get away with anything which is not just the truth, but I believe this baby is not without fault.

We are all prone to say our children are pretty good, and when we see they have an inherent fault we are much inclined to overlook it. I don't blame Mr. Powell for taking that attitude; but, having given me the privilege to speak, I suppose we can point out some of the characteristics of this child. And, if I find that the child has any characteristics, or think it has any, which it doesn't have, I know Mr. Powell will correct me. He knows, possibly, a little more about the child than I do. I am looking at the child from a critical standpoint. He is looking at the child from more of a friendly attitude.

The frogleg winding is, as Mr. Powell has been explaining, simply a combination of two old windings—the multiple winding and the series winding. Now, by combining these two windings he hopes to effect some improvement.

Now, we want to distinguish between frogleg winding having twice as many circuits as poles and frogleg winding having more than twice as many circuits as poles, because the latter has independent windings.

The field of the frogleg winding is not universal. I take exception to the statement that the Arnold windings are not used in this country. This winding is of the series type, yet it is cross connected by connecting equi-potential points in the winding. That is not applicable to frogleg wound machines where you have more circuits than poles.

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When we say "series winding" we mean, generally, the two-circuit winding. We can have a series winding with two circuits on four poles, six poles, eight poles, etc. The six pole machine with a multiple winding has six circuits, the eight pole machine eight circuits, etc.

Now, suppose we have an eight pole machine and we don't want two circuits or eight circuits—the two having not enough commutator bars and the eight too many. We can use the Arnold winding giving four circuits on eight poles or we can have six circuits on twelve poles, or twelve circuits on twenty-four poles. All these windings we have built in the last few years. These windings are working well. That cross connectors work well also is proven by the fact that you are here, for most of your machines are cross connected. We do not try to avoid cross connectors, nor do we conceal them.

In the frogleg winding the cross connectors have been embedded in the slots. And if the cross connectors are likely to give such trouble as you might infer from the paper, then we would not want to embed them in the slots but make them as accessible as possible. The cross connectors, in my experience, are not a great objection in the winding or operation of a machine, because cross connectors are not often troublesome. I won't say that any part of a machine won't break down sometimes, but the cross connectors, when properly arranged and insulated, are probably the least likely to break down. They are located at the back end of the machine, according to standard practice, where they can be well insulated. They don't pass through an iron circuit, and consequently can be better insulated than possible in the slots. When we place a conductor in a slot we place it there because we cannot place it elsewhere and obtain the desired results. If we could make machines and have no conductors in the slots we would do that. When locating cross connectors we locate them where they will be available without disturbing the rest of the armature.

If a cross connector in the slot fails you must rewind. So, in that respect we say the cross connector has not been done away with in the frogleg winding but it is concealed.

I would like to speak about the comparative heating of the two machines referred to in the paper. The temperatures are shown to be very different for the two machines. The low temperature rise is attributed to the benefits effected by the frogleg winding. Mr. Powell has explained that you eliminate certain currents by the introduction of the frogleg winding. I feel that this difference of temperature can be readily explained and that it is not due to the fact that the machine has a frogleg winding. It is due to the fact that the conductor has been sub-divided and the eddy currents have been greatly reduced or eliminated.

Many years ago we had a 1000 KW. generator on test which had a ¼" deep armature conductor. The machine was under question because of the armature heating. This was a high speed machine. We decided to make a new machine with a much smaller armature conductor. The armature with the smaller conductor ran much cooler than the armature with the ¼" conductor. The explanation for this fact is that the eddy currents in the smaller conductor are so much less than the eddy currents in

the large conductor that the total amount of heat generated was much less on the armature with the small conductor.

In the frogleg winding the armature conductor is less than half the size of the conductor in the normal machine. Consequently, in the frogleg winding some of the eddy currents are eliminated, simply due to the fact that the conductor is sub-divided and not due to the fact that the winding is a frogleg winding. In the machine, which I have referred to, the armature conductor was not sub-divided, it was made smaller and the result was a cooler machine.

I would like to make this point clear, that is, that the frogleg winding may be applied to machines and less temperature rise obtained than if the machine had been wound with twice the depth of armature conductor. This fact proves that conductor in the first place was too deep and that within this conductor there were eddy currents. The winding could have been sub-divided without having converted it into a frogleg winding and the temperature would have been reduced.

It is quite possible to sub-divide the armature conductor in most any machine, but any sub-division means less copper and more insulation. You do not split a conductor in a slow speed machine, such as many of you gentlemen have in operation on your reversing mills because the frequency in these machines is so low that you don't have eddy currents in the conductors. We find that it is only in the high frequency machines that extensive eddy currents exist and in such machines the sub-division of the armature might be beneficial, but this sub-division can be done on any ordinary machine. It will not reduce the voltage difference between adjacent commutator bars neither does the frogleg winding reduce the voltage difference between adjacent commutator bars as applied to the ordinary machine to get twice as many circuits as poles.

One of the great disadvantages existing in the frogleg winding is the difference of potential existing between adjacent armature conductors lying in the same slot. The winding, as you have noted in the illustration, is a four layer winding, whereas in the ordinary machine we have a two layer winding. In this four layer winding there is a full difference of potential between adjacent layers. For example, if the machine is wound for 600 volts, there will be a difference of potential of 600 volts between the first and second layer, and a difference of potential of 600 volts between the second and third layer, and a difference of potential of 600 volts between the third and fourth layer. This condition makes it essential to apply much more insulation to the armature conductor, because it is necessary to insulate for full difference of potential, between the four layers whereas on the ordinary machine there are only two layers and the insulation between layers is only one-third as much as is necessary on the frogleg winding.

Some years ago I had the pleasure of reading the paper before this society in which I set forth a proof that the output of a machine was proportional to the total flux and to the ampere conductors on the surface of the armature. Designers have always looked very strongly upon the space factor of the armature winding. By space factor we mean the relative amount of total cross section of copper to the total cross section of the slot. In the ordinary winding of D.C. machines an average condition would be represented by a 50% space factor, that is, the slot space would be taken up by 50% of copper and 50% of insulation. Now, if it is necessary to increase the amount of insulation on account of the four layers in this winding, it is apparent that the amount of copper must be reduced, consequently, the output of a given machine will be reduced by the introduction of this winding. To obtain the same output with the same heating the size of the machine would have to be increased. These facts interest both the manufacturer and the purchaser.

The purchaser is again interested in this matter of insulation. Not because of the reduced output, which the manufacturer might be able to obtain on a given sized machine, but because of the risk entailed by a difference of full potential between layers and the much greater chance for a breakdown when there are four layers instead of two layers. Mr. Powell admits that it is somewhat harder to wind an armature with this winding. It must be very much harder. In applying the armature coil you will find it necessary to bend the front end projection of the winding in order to allow all the coils to be applied. This bend you will observe will come near the ends of the armature iron core. This is where the slot insulation meets the end coil insulation. I do not have to tell this audience that breakdowns are more likely to come at this point than anywhere else in the armature winding. To begin with, this is the weakest part of the coil as the insulation is likely to be less perfect at the junction of the slot insulation and the end coil insulation. By bending the coil at this point a crack in the insulation is easily made. You will find this bend very necessary to make. This goes with a frogleg winding. Such a bending of the coils is unnecessary in the winding of the ordinary machine.

In view of the mechanical and the insulation short comings of this winding, one must feel that there are other great gains in order to justify the putting in of such a winding. Now, is there anything to be gained in, for example, an 8 pole machine with 8 circuits, such as we ordinarily have by changing this machine to a frogleg winding which wuold give 16 circuits on an 8 pole machine. The number of commutator bars is the same and the difference of potential between adjacent commutator bars would be the same. Now, the question is, whether the reactance voltage is modified by introducing this new winding. Each commutator bar has four leads coming into it whereas in the ordinary winding there are only two leads coming into the commutator bar. Now, if we assume that in the ordinary winding the conductor is carrying 200 amperes we would have, in the frogleg winding, a current of 100 amperes per conductor, but the same total current is coming into the commutating bar. Since the number of commutating bars has not been increased, the total current to be commutated in the new winding is the same as the total current to be commutated in the ordinary winding. The time of commutation is exactly the same, the total current to be commutated being exactly the same, the reactance voltage must be approximately the same. That is, with the straight frogleg winding so applied as to give twice as many circuits as with the ordinary

winding, the reactance voltage will not be materially modified.

If this point is refuted I would like to ask wherein the reactance voltage of the new winding is materially modified from the reactance voltage of the ordinary winding? If the reactance voltage is not reduced the improved commutation as described was due to other factors.

We find in this paper a comparison of two windings made on a 1000 KW. 250 volt 750 RPM. generator. One winding having 104 bars and the other winding 420 bars. Now, the latter winding, with so many commutator bars, is not beyond criticism. On account of the large number of commutator bars each bar will be very thin. The commutator will have a large percentage of mica between bars. The amount of work to build such a machine is relatively great and the difficulty to repair is correspondingly great. You naturally desire a machine as simple as possible and with as few coils and commutator bars as will do the desired work satisfactorily. With this large number of commutator bars and large number of armature conductors the insulation of the coils becomes an important factor. This winding in its simplest form will require twice the taping as is required in the ordinary machine. This taping is not only objectionable on account of its initial cost, but the more tape we put in a given machine the less copper we can get in the same machine. The very fact that more taping is required indicates that there are more surfaces to be insulated one from another. In this new winding we have three times the chance of breakdown between layers as we have in the ordinary winding.

Since this winding requires such a large proportion of insulation, it is not possible to conceive that the heating will not be increased as can be readily seen from the description. The lap winding is enveloped in the wave winding. Consequently the wave winding, which is on the inside, has no surfaces which are exposed to the air. Hence, by all the laws of heating, the inside winding will be much hotter than the outside winding. Twenty-five years ago, when we had double commutator machines with double armature windings, the inner winding or the winding which was put on first would burn out, while the top winding would be all right.

Motor speed regulation has not been referred to in this paper, and I would get the idea—if I did not know something about speed regulation—that this winding would give good speed regulation. This frogleg winding has in itself no effect on motor speed regulation. It has nothing to do with it. Speed regulation is obtained by keeping the flux the same from no load to full load, and good speed regulation has been accomplished by combining flux control with other factors. Shifting the brushes of the motor has always been recognized as a method of modifying the speed. We used to shift the brushes on non-interpole machines until sometimes they would race, but shifting brushes I would say is a most unfortunate way of attempting to control speed of a motor on which you desire to obtain absolute speed control. I will tell you why; the brushes will not maintain the same fit on the commutator from day to day. If you could maintain a perfect brush fit you might maintain the same speed condition, but where the brushes are loose in the holders and the commutator a little rough the brushes may bear more on the toe than on the heel or visa versa, and the armature reaction will not remain the same. Consequently, the speed will be modified. We all make the best brush riggings that we can and we endeavor to obtain good brush fit, but under the best conditions you will find variations from day to day. These variations will effect the speed regulation and it is difficult to obtain a speed regulation within ½ of 1 %. We have obtained speed regulation within ½ of 1%, but a slight change, such as may be produced by a little dirt on the commutator or the sticking of the brushes in the holders changes the brush fit and slightly modifies the speed.

Speed regulation to be satisfactory, I think, must be inherent in the machine. The flux changes should be controlled, consequently it is desirable to neutralize the armature reactions. The frogleg winding offers no advantage in this respect. The fact that the frogleg winding permits a shift of the brushes simply shows that the machine has a wide neutral. The width of the neutral in any design is controllable and should be made to suit the commutating zone through which the conductors move during commutation.

I feel that this about covers the comments I have to make on this winding and if Mr. Powell cares to answer any of these questions which I have raised I would be glad to hear his answer.

C. S. Proudfoot: I would like to ask Mr. Powell to hold that answer until we have one or two more questions, as the time is getting late.

We would like to hear now from Mr. Page of the General Electric Company.

H. S. Page*: The novel feature described in this paper consists of a scheme to combine lap and wave windings on the same armature in such a manner that one acts as an equalizer for the other. The scheme appears to have most of the advantages claimed by the authors, but this paper could hardly be considered a disinterested presentation of all the facts as the disadvantages are not even given casual mention.

In order to obtain this combination of winding and equalizer all in the same slots it is necessary to build up four layers throughout the slot and end windings. Referring to figure 3, which shows a diagramatic layout of a four pole machine with frogleg winding, segment $1_1 2_1$ can be considered as under positive brushes and $7_1 8_1$ under negative. By tracing out the diagram to the slots it will be seen that the bottom conductor is positive, second negative, third positive and fourth negative. This means that full machine potential exists in three places between adjacent conductors in every slot, which is three times the hazard that exists when the ordinary two layer construction is followed. Partly offsetting this advantage for the two layer winding is the fact that it requires a set of equalizers.

The construction of the four layer winding is such that in addition to being insulated to withstand full potential the coils are grouped together and taped again in order that they may be assembled. This additional taping only serves as heat lagging and makes it more difficult to obtain the actual

*Engr., General Electric Company, Schenectady, N. Y.

operating temperature of the coil. The ordinary two layer winding requires no such surplus lagging.

With these coils taped together it is difficult to see how the winder assembles the coils without distortion of the end windings at the bend just outside the core portion. This springing of the insulated bar tends to open up cracks in the insulation at the point where it has been my experience a majority of the burnouts occur.

In regard to performance, the general claim for the frogleg winding is: better commutation and lower heating, which, in other words, means more available capacity for the same size machine.

Commutation is subject to difficulties almost too numerous to mention and as the only claim for improved commutation is based on better equalization of the armature circuits the comparison must have been made with an armature having a decidedly inferior type of equalizer. As a matter of fact, some of the frogleg wound motors have been reported as sparking quite viciously in operation when loaded at considerably less than their rated capacity. Undoubtedly these motor armatures had perfect equalization, but the commutation trouble was due to some of the many other possible causes.

A comparison of heating between a frogleg armature machine and one without this four layer winding, as cited under part II, shows very much in favor of the frogleg winding. I believe in this case, if the designers had used the same care in proportioning both sets of windings, that very little difference in the losses and resultant heating would have been obtained. I have in mind an installation of ten 2500 kw. generators where it was necessary to determine the exact efficiency under operating conditions. After a series of very careful tests both by input-output and segregated loss method the total load loss was found to be less than 0.6% at normal rated load. Had these generators developed such losses as suggested by the temperature comparison in the paper the load losses would have amounted to several per cent. The results of these efficiency tests can be cited as a fair example of what can be accomplished with the ordinary two layer winding.

The multiplex winding scheme described is well adapted to high speed high current machines, but on such apparatus the mechanical construction of the commutator becomes a limiting feature. This same method of so selecting the slot arrangement that the various windings could be equalized with each other was explained to me at least twelve years ago by a designer of turbo generators. He had several such machines in successful operation, all with high speed shrink ring commutators, which, of course, required more attention than would a slower speed generator.

C. S. Proudfoot: We have a written discussion from Mr. A. C. Bunker, Chief Engineer of the Crocker-Wheeler Company, and we would like to have enough time for the Secretary to read this.

NOTE: Mr. Powell's written discussion of Mr. Bunker's letter has been interpolated.

A. C. Bunker:* Referring to the article by Mr. W. H. Powell and Mr. G. M. Albrecht on page 345 in the September issue of the Iron and Steel Engineer:

We have the following comments and criticisms to make about the various statements and details brought out in this paper:

The frogleg winding uses two different kinds of coils.

There are twice as many coils in an armature core slot to be made, insulated, put in place and soldered as on ordinary machines.

The slot is therefore deeper and the co-efficient of self-induction of an armature coil is greater.

The space factor for the winding is less.

W. H. Powell: These comments referred to certain details of manufacture and design. It is true that there are two kinds of coils and twice as many to insulate and solder into the commutator necks. There is, however, no more soldering to be done at the commutator necks than with the standard armature, but we have no cross connectors either at the back or front end, and the labor involved in the insulating, installing and soldering more than offsets the additional material and labor cost of the frogleg coil. As explained elsewhere in detail in this discussion, the slot is slightly deeper and the space factor slightly less, but the armature runs cooler and the commutation is very much better than for the ordinary machine.

A. C. Bunker: The statement is made that Prof. Arnold developed a system of cross connectors which **overcame to some extent** the burning of alternate bars.

Arnold's series parallel winding gives completely satisfactory results when properly designed to permit correct equalization.

W. H. Powell: In Mr. Lamme's paper, entitled "Development of the D.C. Generator," published in the "Electrical Journal" and re-printed in his book entitled "Electrical Engineering Papers," we find the following statement which refers to this type of winding:

"Prof. E. E. Arnold of Karlsruhe, Germany, developed the system of cross connections for such armature windings which, **to a great extent,** overcame this burning action at the commutator." Mr. Hall has also referred to this type of winding, which he has used successfully on certain small machines. In Mr. Hall's discussion of this type of winding, he says: "It is a difficult matter in a small machine to put in cross connectors and find equi-potential points." I gathered from his remarks it was used rather rarely and in any event this type of winding is not used to such an extent as the lap winding and like the lap winding it requires cross connectors in order to function properly.

A. C. Bunker: External cross connectors are no more dust catchers than the armature coils themselves.

Cross connectors can be more easily and more effectively insulated from ground than any coils in the slot can be.

Any troubles experienced by the authors due to shortening of external cross connectors was due to imperfect insulation or to mechanical difficulties and not because of the cross connectors.

W. H. Powell: It is my own experience that the cross connectors either on the front or back of

*Chief Engineer, Crocker-Wheeler Company, Ampere, N. J.

the armature usually catch more dirt and are more difficult to clean than the armature coils themselves. In any event the absence of cross connectors makes one less dirt catcher. His statement that the cross connectors can be more effectively insulated from the ground than any coils in the slot may be perfectly true, but it is more difficult to insulate them from each other, and if they carry abnormal circulating currents they are liable to roast out and short circuit the coils. If no cross connectors are used this danger is eliminated.

A. C. Bunker: Where an armature coil is used as a balancer it has to pass through two core slots before equi-potential points are connected. It is, therefore, subjected to the inductance produced by the core teeth and the balance or equalization cannot be as good, nor the resistance of path between equi-potential points as low, as would be given by external cross connections.

W. H. Powell: Tests prove that the balance or equalization is better for the reason that the armature is in effect 100% cross connected. The magnitude of the circulating currents as shown by the test, which we referred to in the paper in which one field pole was short circuited and the armature operated at 100% overload were so surprisingly low that there was no abnormal heating of the armature coils.

A. C. Bunker: In paragraph under figure 7 the statement is made—"If the magnetic strength of the poles is not equal, the current flowing in the two circuits will be proportional to the voltage generated."

The short circuit current will be proportional to the difference between the generated voltage divided by the resistance of the eight poles in series.

W. H. Powell: Neither statement is rigidly correct. They both say the same thing in a little different manner and both convey the idea that currents in the two circuits are unbalanced, which shows the object of the authors in making the statement.

A. C. Bunker: Referring to test data given on second column, page 350, Machine "A" is tested at 278 V. and machine "B" at 250 V.

It seems a fair assumption that machine "A" is a 250 Volt generator and by increasing its voltage to 278 the magnetic density, leakage fields, core losses and load losses were increased and any irregularities due to structural or other reasons were magnified. The statement is that these machines were of identical constructions.

Under the above conditions this is evidently unfair to Machine "A."

It might also be assumed that as the short circuit and load losses on Machine "A" gave such temperatures as reported, it might have shown unfavorable with Machine "B" if it had been provided with frogleg winding. It may also be that Machine "A" did not have proper cross connectors.

W. H. Powell: Replying to the last statement first, the paper distinctly states that Machine "A" was wound in the ordinary way, three coils per slot and cross connected every slot, that is, every third bar. His statements are true regarding the magnetic density, leakage fields, core losses, etc., were increased. Nothing is said about the commutator which ran 20° cooler although it was carrying 10% more current. It has been my experience in testing large machines that if the voltage is raised 10% and the current reduced a similar amount so that they are operating on the same kilowatt load there would be no such difference in the temperature of core and coils as indicated by this test. As shown by the test, the shunt field coils ran hotter as to be expected and the interpole coils ran cooler as to be expected on the 275 volt machine.

A. C. Bunker: Balancers on every slot do not always give good balance.

Balancers on every bar have been used on machines as small as 100 K W.

It is just as practical to have cross connectors on every bar with smaller machines as for the large machines with many poles.

It is no harder to make soldered joints for cross connectors at the rear of armature coils than it is to solder commutator tails.

W. H. Powell: These are very general statements regarding design and construction of machines which cannot be answered completely in a few words. Answering these statements in their order:

If balancers on every slot do not always give good balance, then it is fair to assume that balancers on every coil would give better balance and that is what is accomplished by the frogleg winding.

If balancers on every bar have been used on machines as small as 100 kilowatt, it is fair to assume that the machine required them, as it is very difficult to find the room for cross-connecting every bar on a small machine except one which has a comparatively small number of bars, that is, a high speed turbine driven generator or a low voltage machine. How much simpler and easier to clean would be a frogleg wound armature than one with this big mass of external cross-connectors. If the machines referred to in point No. 14 are multi-pole lap wound armatures, it is expensive to cross-connect every bar on a machine of any size and it is mechanically impossible to do so on small machines of reasonable speed and standard voltages. The number of cross-connectors used in general is dependent upon the room for same and the expense involved in connecting them up. If the cross-connectors are put on the back of the armature, it may be no harder to make the solder joints for cross-connectors, but every joint has to be carefully insulated and the cross-connectors themselves rigidly fastened to the armature spider. In a large, slow-speed machine of high voltage, with a large number of armature conductors, the expense involved in installing the cross-connectors and soldering same to the armature coils is as great as the labor cost of winding the rest of the armature and if such an armature has to be repaired in the field the time during which the machine is out of commission is very much greater than would be the case with the frogleg winding.

A. C. Bunker: The conditions laid down in the paper for successful commutation on D.C. machines are easily met by machines with simpler winding and with external cross-connections.

Load losses need be no greater in machines using simpler windings than claimed for by the frogleg winding.

W. H. Powell: If the volts per bar can be kept within well-defined limits there is no doubt in any one's mind but what there are thousands of machines operating successfully with the simpler winding winding and with external cross-connectors.

A. C. Bunker: The commutating zone can be sufficiently great for all practical and useful purposes with machines of simpler winding.

W. H. Powell: Where it is not necessary to shift the brushes in order to adjust the speed regulation of a motor or the compounding of a generator in order to obtain satisfactory parallel operation, a wide commutating zone is not necessary. If, however, we can obtain a wider commutating zone with successful commutation as obtained with the frogleg winding, it is sometimes an advantage to shift the brushes in order to obtain the proper speed regulation of a motor or the compounding of a generator without making it necessary to change the field strength by means of external resistance or shunts.

A. C. Bunker: Machines of simpler winding can be found that have carried 100% overloads for sustained periods where the external cross-connectors were not as frequent as one per bar.

W. H. Powell: In those cases the machines have probably been under-rated because any normal rated 40° machine will burn out if it carries sustained 100% overload.

A. C. Bunker: The machines with simpler winding are made with the volts per bar well below troublesome values and operate sparklessly with currents per stud equal to those given in the paper.

W. H. Powell: The machines referred to in the paper are not abnormal machines as regards rating and speed. Referring to the design of the quadruplex frogleg mentioned on Page 350. It would be possible to lengthen out the armature core so that the magnetic flux will be twice as great, in which case it wolud be possible to rate the machine 2000 kilowatts, 500 volts, 750 RPM. The average volts per bar 9.6 and the maximum 16. Such a machine rated at 2000 kilowatts, 500 volts, 750 RPM, would be practically impossible in case the simpler winding was used.

A. C. Bunker: The modern type of standard machine can be loaded and operated electrically in a satisfactory manner to a point that closely approaches the mechnical stability of the machine, and it is difficult to see how anything would be gained by complicating the winding.

The trend in machine design, like most everything else, has been for the past several years toward simplification, but the frogleg winding does not seem to be in this direction.

W. H. Powell: It may be difficult to see this after carefully reading the paper, but there was no difficulty in convincing a large number of prominent engineers who witnessed some of the tests described in the paper that the frogleg coil certainly commutated better and handled unbalanced loads better than the ordinary standard machine.

What are cross-connectors for? To reduce the heating due to unbalanced circuits and to improve commutation. The frogleg coils perform both these functions without any cross-connectors. If simplification is the criterion, it would seem that the elimination of the cross-connectors would be a step towards simplification.

C. S. Proudfoot: I will now ask Mr. Powell to answer the questions.

W. H. Powell: There have been so many points brought up that there will not be time to answer them all verbally. As Mr. Bunker is not here, I will answer his comments and criticisms in writing. Mr. Hall has asked certain questions and I will ask him to repeat them.

D. Hall: Is there anything to be gained in an eight-pole machine, with eight circuits, when you change it to a sixteen-circuit machine?

W. H. Powell: "The proof of the pudding is in the eating." We have built machines both ways. We have built these frogleg windings on small machines. We have some machines we are building for the moving picture industry, that are low voltage machines. They have to stand tremendous overloads for short times. We have found that with the ordinary windings and ordinary cross connectors they will stand twenty five per cent overload before there will be any signs of sparking. However, when we get it up to fifty or seventy-five per cent, we get visible sparking—we get successful commutation, but get sparking.

We built the same machine with the frogleg coil, and ran it up to seventy-five per cent oevrload, and you could not tell there was a load on it by looking at the brushes. The fact is, we get better commutation and cooler commutators.

Mr. Hall also spoke about the reactance. I would not undertake to say whether or not that is reduced in the frogleg coil. There is, however, a different condition in the coils undergoing commutation in the frogleg winding than is the case with the ordinary winding. In Fig. 5 is shown a diagram of lap wound armature coils under two north poles, and also the modification of same by a dotted line. Suppose the brushes are set so that they cover bars 1_1 2_1 and 1_2 2_2. In the standard armature the path of the short circuit current of the coil on the right would be 1_2 A_2 C_2 B_2 2_2, and through the brush surface back to 1_2. In the frogleg winding, that is, if the conductors B_1 C_1 and A_2 and C_1 were split and joined at "E," as shown by the dotted lines, only one-half of the short circuit current would follow that path. The path of the other half would be 1_2 A_2 E B_1 2_1 through the brush surface to the brush on the left and back through the brush cross-connector to the brush on the right and back through the brush surface to 1_2. In this case there is the addition of the resistance of the two brushes on the short circuit path. This may be one reason that the commutation is better.

Now as far as reactance voltage is concerned, in order to obtain satisfactory commutation, the interpole strength must be adjusted so as to produce a suitable commutating field to overcome the reactance voltage and in order to reduce the short circuit current. We find in measuring the contact drop under various parts of the brush surface that the distribution of current under the brush appears to be much more uniform in the frogleg armature than is the case with the standard armature. We also find that with machines exactly alike in other respects, the frogleg coil will commutate very

much heavier overloads than the standard armature without any visible sparking.

What is the next question, Mr. Hall?

D. Hall: The heating.

W. H. Powell: Mr. Hall, Mr. Page and Mr. Bunker have all emphasized the fact that our space factor is less. Suppose you have a slot 2″ deep. Now we will allow .2″ for your wedge. That leaves 1.8″. You need, say, .05″ for insulation on the top and .1 between coils and .05″ at the bottom, that is .2″ for insulation. That leaves 1.6″ for copper and you have two conductors .8″ in depth. Now what have we got? We use two conductors .4″ instead of one conductor .8″. We require .2″ more space for insulation between coils, as we have four coils instead of two, our slot will be 2.2″ deep, or 10% deeper and no wider. Hence, our space factor is slightly less, but our armature will run cooler and the commutator better. So much for space factor.

Now as regards heating of the lower conductors. This has been discussed before in reply to Mr. Cummins' question. As most of the heat is conducted through the side of the coil, there is no reason why the two lower conductors in the frogleg coil should run any hotter than the lower conductor in the standard armature, provided, there is the same amount of heat to be dissipated, as the conducting surfaces to the teeth are equal. As a matter of fact, there is less heat in the frogleg coil because the eddy currents are less and the armature actually runs cooler as proved by tests. Any other questions, Mr. Hall?

D. Hall: Well, I think your point about the overload capacity—I would like to call attention to normal multiple wound armatures. We had one on test yesterday with three times the load it ordinarily carries. If we had a frogleg winding we might say it was due to that; but we have had much greater load than you specified; and that has carried ten times the ordinary load.

W. H. Powell: I am not decrying the ordinary machines in any way. I say this; if a few cross-connectors are good, a lot of cross-connectors are better.

D. Hall: Permit me to make one more statement: With cross-connecting every slot and cross-connecting every bar we could not distinguish the difference in the operation. One had twice as many cross-connectors as the other.

W. H. Powell: All the comment I would make is that you have a very good machine. Don't understand that this is a cure-all. We must have a good commutator and properly adjusted interpoles and suitable brushes. You said you would put four hundred and twenty bars up against the one hundred and five bars—and then you said a two hundred bar commutator would be better. The point I am raising is this; if you would design the machine along the lines we did, with the same magnetic flux, you would only have had one hundred and five bars. How could you get two hundred bars? Do you make machines with double circuits?

D. Hall: Yes, with twice as many circuits as poles.

W. H. Powell: Is that your common practice?

D. Hall: We only make a machine with double the number of circuits where we have comparatively high speed and comparatively low voltage. In mill motors, as commonly designed, you have twice as many bars; but on the two hundred and fifty-volt machines it becomes sometimes advisable to have twice as many circuits as poles.

How do you connect any frogleg winding in an odd number of slots in an armature with some odd number in the circuits?

W. H. Powell: In the first place, I cannot conceive an armature with an odd number of circuits. Both series and multiple armatures have an even number of circuits. We have adapted the frogleg coil to multiple wound armatures only, in which cases you have cross-connectors at equipotential points. In any such standard armatures you can put in the frogleg coil and it will work better than the standard wound armature. In regard to the odd number of slots. A multiple lap wound armature ordinarily has an even number of slots and bars. It is possible, however, to have an odd number on a six-pole machine and in this case you have an odd number of bars per pair of poles, that is, your equal potential points are the total number of commutator bars divided by three, which might be an odd number. In this case the frogleg coil could be used.

There is one point Mr. Hall brought up about those duplex wave windings, in which he used a fewer number of circuits than he had poles—if a six-pole machine, it might have four circuits?

D. Hall: Usually half the number of circuits.

W. H. Powell: It is necessary to cross-connect that.

D. Hall: Yes, quite advisable to; but don't have to cross-connect every bar. They are very small capacity machines.

W. H. Powell: How large?

D. Hall: Small machines in which your volts per bar would permit. We have tried those machines without the cross-connectors and found them to be a failure; that is, on the small machines. It is a difficult matter in a small machine to put in cross-connectors and find equipotential points.

W. H. Powell: We can wind it with multiple winding, and put in frogleg winding, and overcome all our troubles—and have no cross-connectors.

D. Hall: You don't mean you have no cross-connectors?

W. H. Powell: We have no cross-connectors.

D. Hall: How do you equalize?

W. H. Powell: Every coil is a voltage generating current carrying conductor. This coil here (indicating the lap coil) generates a voltage and carries a certain amount of current. This one (indicating the wave coil) carries an equal amount. We are using the best features of both the multiple winding and the series, and are working them as a team. There are no external cross-connectors on the armature of any description.

D. Hall: You don't understand. There are equalizing currents, are there not, if the poles are unbalanced?

W. H. Powell: True.

D. Hall: Where do those equalizing conductors pass through?

W. H. Powell: This question was asked by Mr. Cummins early in the discussion, but I will repeat.

The function of cross-connectors is to carry circulating current to the coils in case the magnetic circuit is unbalanced. Furthermore, the more you cross connect the less the magnitude of those currents. That is the reason we put in more cross-connectors. As explained, if you put in three you are going to get a black spot between; if you put in six you may get one in between and then you put in twelve, finally you get to such a point that you get agood machine. In our case we obtain those circulating currents in the armature coils without the use of external cross-connectors and as the frogleg field is in effect 100% cross-connected, the magnitude of the circulating current in the frogleg coil is reduced to a minimum.

There is another thing I want to say, in closing—that has not been mentioned except in a general sort of way; that is, this maximum capacity spoken of by Mr. Lamme. The late Mr. Lamme, who was chief engineer of the Westinghouse Company, and who perhaps did more for the development of the direct current machine and for the alternating current machine than any other man—presented a paper before the Institute of Electrical Engineers a number of years ago on the subject of the "Physical Limitations of D.C. Machines." Now, in this paper he had to start with certain assumptions. Among others, he states that the maximum volts per bar is one of the most important considerations. And in this mathematical analysis he mentions the average volts per commutator bar has to be 14 3-10, and the maximum as 21—allowing for a twenty-five per cent increase by flux distortion.

That is what he starts with, and he develops this mathematical analysis and obtains certain equations on the basis of the ordinary standard wound machine; that is, the machine with one coil per commutator bar.

In this analysis he reaches certain conclusions. He states, for example, that a fifty-cycle generator has a maximum of kilowatts per pole varying from one hundred and forty-two, with a one-inch depth slot, down to one hundred twenty-three, with a two-inch depth slot.

Assuming it is one hundred twenty-five—a round number—you have a twelve-pole machine, fifty cycle. That would be 500 revolutions. That capacity would be fifteen hundred kilowatts. In other words, he regards that a fifteen hundred kilowatt machine at 500 RPM would be the maximum size which would be considered good engineering with one coil per commutator bar.

We are building some 12-pole machines at 500 RPM which have a capacity greatly in excess of 1500 KW.

This is what he says in conclusion: "The results obtained are predicated upon parallel type of windings with a minimum of one turn per armature coil." That is, a standard lap wound armature. "Ji types of windings having the equivalent of a fractional number of turns per coil less than one turn per coil"—that means, if it is a duplex, it would be one half of one turn or one conductor; if triplex, one-third of one turn; if quadruplex, one-fourth of one turn—or one-half of one conductor.

I will read again: "prove to be thoroughly satisfactory for large capacity machines, then the above maximum capacities can be materially increased. However, accepting the results as they stand, the limits of capacity as fixed by commutation are as high as other conditions will allow."

If we have developed a machine which has the equivalent of a fractional number of turns per commutator bar, and we have built it economically, we have certainly advanced the state of the art—in the increase of capacity of machines for a given speed, or increasing the speed for a given capacity.

A Member: And there is the question about shifting the brushes.

W. H. Powell: Mr. Hall has mentioned that in his discussion. If I understood him correctly, he conveyed the idea that every time we wanted to change speed, we had somebody there to shift the brushes and he discussed at some length the fit, and that if you shifted the brushes you changed the fit of the brushes on the commutators. The idea I meant to convey was that the **speed regulation** of a motor could be changed by shifting the brushes and when once shifted, they stayed put. Suppose after you get the machine installed you want to be able to change the speed regulation. We have an easy means of attaining it by slightly shifting the brushes. If the brush rigging is constructed properly, this ought not to spoil the brush fit. In any event, a very slight sanding would be sufficient. He stated that in certain respects you can do that with your interpoles. True, but we have found that with this machine that we do have a wider neutral or rather a wider commutating zone under the interpoles in which we are able to obtain satisfactory commutation and we can change our speed regulation in this manner if it is found necessary to do so.

C. S. Proudfoot: If you have any other questions, we would like to have you bring them up in writing; and they will be replied to in writing, and they will be in the minutes of our meeting.

Note: The following discussion was written after meeting adjourned.

Question: Does not the frogleg winding, with its improved commutation, permit the use of a longer core, which permits the use of a smaller diameter of armature for a given rating?

Does not the use of this winding permit you to use higher speeds for a given rating or much larger capacity at a given speed?

Answer: The output of a given armature is a function of the square of the diameter and the length of the core. It is termed the D^2L.

On the other hand, the magnetic flux is a function of the diameter and length of core. It is termed the DL. It is apparent, therefore, that on comparing two armatures of the same D^2L, the one with the smaller D will have a considerably larger DL; that is, larger magnetic flux.

Comparing two machines of same output, number of poles, voltage and speed, it is evident that the long, small diameter armature which has the greater flux per pole, will require a fewer number of coils per pole, to generate the voltage.

In other words, the average volts per coil is higher. Now the volts per bar at which it is safe to operate is a very definite quantity.

In the ordinary armature, volts per coil and volts per bar are the same. It is apparent from what has

already been said, that a multiplex frogleg winding permits of reducing the volts per bar to 1/2 or 1/3 or 1/4 of the volts per coil. Hence, with this type of winding we can use armatures with a smaller D and larger DL.

As regards higher speeds for a given rating or larger capacity for a given speed.

In an economical design of armature, the peripheral speed is an important consideration, and the maximum peripheral speed is a fairly definite quantity.

It is apparent that with a definite maximum peripheral speed, the smaller the diameter, the higher the angular speed; that is, RPM.

If, therefore, the design is limited to volts per coil, it is possible to design a generator with a multiplex frogleg winding for a given output with a smaller diameter of armature, larger magnetic flux and higher rotative speed than with the standard winding.

On the other hand, if the speed is fixed and also the diameter of armature, it is possible to increase the length of armature which increases the magnetic flux and the volts per coil, but with a multiplex winding, keep the volts per bar within safe limits. This means increased capacity at a given speed.

Question: Does not the limit of amperes per stud remain unchanged regardless of the type of armature winding?

W. H. Powell: In comparing the difference in commutating conditions between two machines of same size and rating, except that one has a standard armature and the other has a multiplex, it is perhaps sufficient to say that there is the same amount of current to be commutated in the same time, so that it would appear that approximately the same strength of interpole would be required to obtain satisfactory reversal of the current under the brushes, under normal operating conditions.

In a duplex winding there are twice as many bars with one-half the current in each, so that the amount of current per coil to be reversed is one-half, but the time of reversal is also reduced so that the pulsations under the brush surface are one-half the amplitude, but at greater frequency.

Hence, the current distribution under the brush surface is much more uniform and gives more ideal commutating conditions.

When the machine is operated under a heavy overload, these pulsations are greatly increased in magnitude and have a tendency to produce sparking or glowing of the brushes. For this reason the duplex winding would appear to be better adapted to withstand overloads as the current is more uniformly distributed under the brush. And in testing machines of same capacity with both kinds of armature this has proved to be the case, and in measuring the voltage under the brush, it is found to be much more uniform in the duplex than in the standard wound armature. From these tests it would appear that the limit of current per stud can be raised on the duplex winding, especially on machines requiring momentary heavy overloads. What is perhaps more important is the limit of K.W. per pole than amperes per pole and this has been discussed.

Replying to Mr. Page's discussion: The space factor of the armature slots, and the heating, and the potential between coils in the slot have been fully covered in the discussion by President Cummins and Mr. Hall. It is admitted that the slot is slightly deeper to take care of the additional insulation top and bottom for four coils instead of two. But the slot is not wider and no more insulation is required on the sides. Hence, his statements that additional tape on the sides serves as heat lagging does not obtain. In reference to coil distortion in winding the armature, there is no such thing. This point was covered in the discussion of President-elect Schaeffer.

There is only one point made by Mr. Page which has not been fully covered in the previous discussion, namely, commutation. It is true that commutation, as suggested, is subject to many difficulties, such as roughness of the commutator surface, in proper fit and spacing of the brushes, improper adjustment of the interpoles and distortion of commutator due to excessive heating. Our claims for improved commutation are not only based on better equalization of the armature current, as stated by Mr. Page, but also on better distribution of current under the brushes and also reduced temperature rise on the commutation surface. The comparisons made on page 350 of the September issue of Iron and Steel Engineer between two 750 KW generators was not, as stated by Mr. Page, with an armature of decidedly inferior type, but one which is as completely cross-connected as any commercial armature of similar capacity, namely, twenty-nine cross-connectors per pair of poles. That certainly would not be called a decidedly inferior type of cross-connection.

Mr. Page also says: "As a matter of fact, some of the frogleg motors have been reported as sparking quite viciously when operated at considerably less than their rated capacity." Since this statement was made we have made a very careful recanvass of all apparatus using frogleg windings and have failed to find a single case where any frogleg wound motors are "sparking viciously when operated at considerably less than their rated capacity." We would be glad to furnish anyone interested with a complete list of apparatus using frogleg windings in order that they may personally investigate their operation.

In closing this discussion I wish to emphasize one more point, namely commutator heating. There have been many details discussed by the chief engineer of direct current design of our three principle competitors, but not a single comment has been made on the reduction of temperature on the commutator with the use of the frogleg winding. I think ever operating engineer will agree with me that a cool running commutator does not require the attention that a hot running commutator requires. If we have done nothing more than improve the operating conditions of commutating machines in reduced commutator temperatures by the use of the frogleg winding, we have advanced the state of the art in the design of direct current apparatus.

*Discussion: Extending the Heat Cycle in Boiler Rooms By the Use of Preheated Air for Combustion Purposes**

Waldemar Dyrssen†: I have not very much to add to the paper in regard to the advantages of preheated air for boilers. They are so well known and the increasing demand for good air heaters indicates that the advantages are fully recognized.

I might add, however, that the impression might be gotten from the paper that preheated air is best or most in demand for stoker-fired boilers, but this is not so. Preheated air offers just as many advantages and in some cases considerably more advantages with many other kinds of fuel, such as powdered coal, oil or gas and especially for blast furnace gas and other low grade fuels such as coke breeze, which you gentlemen have to deal with in steel works. Such works are already large users of preheated air for combustion purposes in metallurgical furnaces such as melting, heating and blast furnaces, where it is a necessity, but there is an increasing demand for preheated air even for boilers in order to increase their fuel economy, which, in most cases, is rather poor in steel works.

I want, however, to tell you about a new type of air heater, which is recently put on the market by the company with which I am connected, as I think it might prove of interest to you, because it is not generally known yet.

Figure 1 shows a general working diagram of this heater. It belongs to the regenerative type, but it has certain novel features. The heater has three compartments in which the heating elements are placed. Each of these compartments has two mushroom valves in top and bottom, which are hooked up in pairs, as shown. Below and above these chambers are other compartments of flues, which extend over all three chambers as shown. Hot waste gases enter the lower right flue and flow through the chambers where the right-hand pair of valves are open into the upper right flue, and from there to an exhauster, as shown. In passing through the chambers the heat is taken up by the heating elements, which consist of a large number of thin, steel plates. The air is blown into the upper left flue and enters the chambers, in which the left pair of valves are open and extract heat from the steel plates before entering the lower left flu, from which the hot air flows to the combustion chamber.

Some of the novel features are the way the valves are arranged, and the way they are operated in connection with the three chambers. The valves are continuously operated by a mechanism placed on top of the heater. This mechanism consists of a shaft which is continuously driven at a very low speed. This shaft has three cams which are placed at an angle of 120° from each other. Each cam works against rollers on a rocker, which alternately is fulcrumed at the left and at the right side, and the valve lifting rods are lifted by the ends of this rocker. The result of this motion is that the valves are alternately lifted during a certain interval of time and held stationary for another period and are lowered during a third period. The exact motion of the valves depends on the shape of the cam and the mechanism acts in such a way that one pair of valves are completely closed before the other pair opens, so that there is no short-circuiting of air to the waste gases. The valves are also so hooked up to the lifting rods that they also seat themselves by their own weight regardless of the relative expansion of the rods and the casing.

A diagram of the valve motion is shown on Fig. 2. Each pair of valves open continuously during 60° turn of the camshaft, stay open during another 60° and close during the next 60° and remain closed during 180°. During any one moment it can be seen from the diagram that the total valve opening for either air or waste gases corresponds to one full valve opening and that air and gas valves in the same chamber are never open at the same time. The result is an absolute, continuous flow of both air and waste gases through the heater and the valve motion is so slow that no shocks can occur due to the valves opening or closing. If, for instance, the camshaft makes one revolution in two minutes, the time for raising the valves will be twenty seconds and the same for lowering.

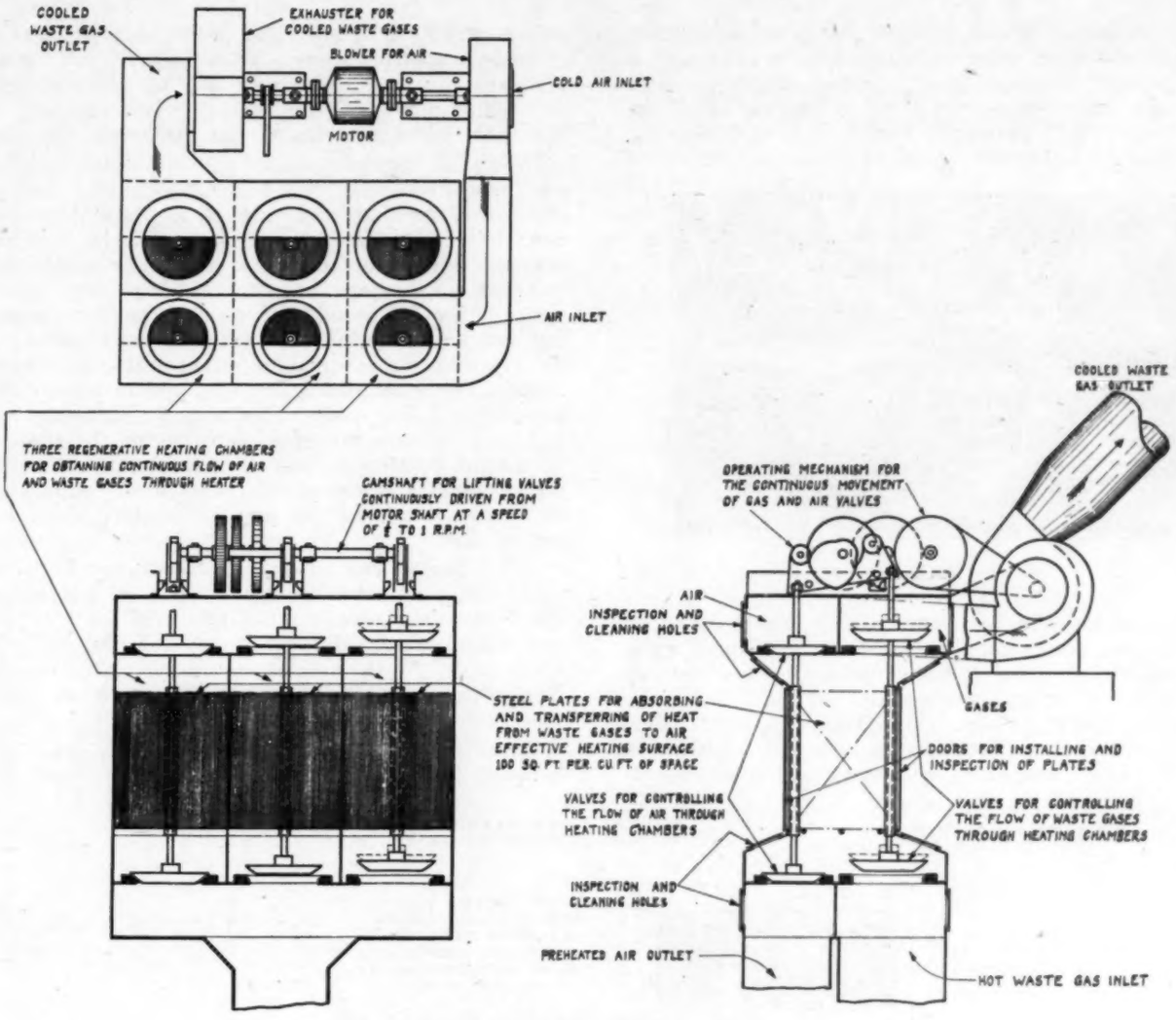
The loss of air due to the free volume in the regenerative chambers will be from one to two per cent, and is therefore practically negligible. It is also possible to produce exactly pure heated air at a slightly increased loss of air by having the gas outlet valve close a fraction of a second after the opening of the air inlet valve, so that the chamber is purged from waste gases before heated air is produced.

Fig. 3 shows the casing of a heater which is nearly completed in our shop. The figure shows the three chambers with doors for introducing the steel plates. There are also numerous handholes for inspecting and cleaning all parts of the heater.

In Fig. 4 are shown the valves and the heating elements, which consists of plain steel sheets 1/16" thick. There are projections pressed out at proper distance to keep the sheets apart. The sheets are shown packed solid, but by turning every other sheet in the pack around they will occupy four to five times more space and the distance between them will be 3/16 to 1/4". This has been done with the upper five or six sheets, which are shown with a space between them. This particular heater has a heating surface of 1,100 sq. ft. and is designed to heat about 6,000 pounds of air per hour. The height, except the operating mechanism, is 5'4", the length 3'9" and the width 2'6".

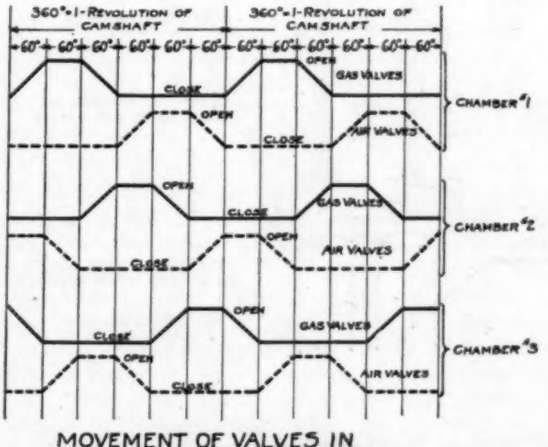
*Paper presented before Twentieth Annual Convention.

†Chief Engineer, Hammer Weld and Furnace Equipment Departments, Blaw-Knox Company, Pittsburgh, Pa.


COOLED WASTE GAS OUTLET
EXHAUSTER FOR COOLED WASTE GASES
BLOWER FOR AIR
COLD AIR INLET
MOTOR
AIR INLET
THREE REGENERATIVE HEATING CHAMBERS FOR OBTAINING CONTINUOUS FLOW OF AIR AND WASTE GASES THROUGH HEATER
CAMSHAFT FOR LIFTING VALVES CONTINUOUSLY DRIVEN FROM MOTOR SHAFT AT A SPEED OF 1 TO 1 R.P.M.
COOLED WASTE GAS OUTLET
OPERATING MECHANISM FOR THE CONTINUOUS MOVEMENT OF GAS AND AIR VALVES
AIR INSPECTION AND CLEANING HOLES
GASES
STEEL PLATES FOR ABSORBING AND TRANSFERRING OF HEAT FROM WASTE GASES TO AIR EFFECTIVE HEATING SURFACE 100 SQ. FT. PER CU. FT. OF SPACE
DOORS FOR INSTALLING AND INSPECTION OF PLATES
VALVES FOR CONTROLLING THE FLOW OF AIR THROUGH HEATING CHAMBERS
VALVES FOR CONTROLLING THE FLOW OF WASTE GASES THROUGH HEATING CHAMBERS
INSPECTION AND CLEANING HOLES
PREHEATED AIR OUTLET
HOT WASTE GAS INLET

BLAW-KNOX PATENTED CONTINUOUS REGENERATIVE AIR HEATER

FIG. 1



MOVEMENT OF VALVES IN BLAW-KNOX PATENTED REGENERATIVE AIR HEATER

FIG. 2

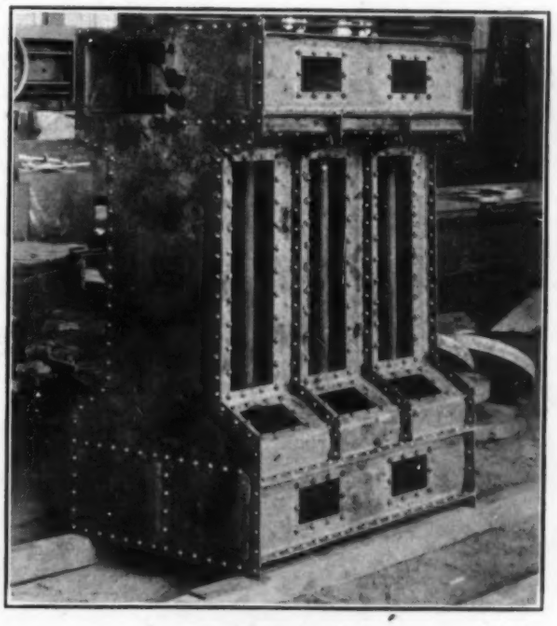


FIG. 3.

This type of heater is now being manufactured in eight different sizes, ranging from a capacity of 6,000 pounds of air per hour to about 138,000 pounds. This last heater measures 18'8" in height, 19'10" in length and 12'7" in width, and will have a heating surface of about 50,000 sq. ft. The amount of waste

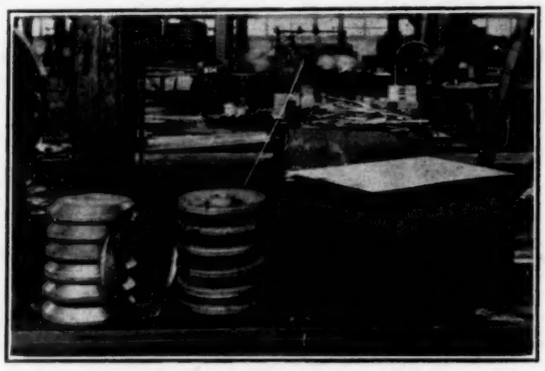


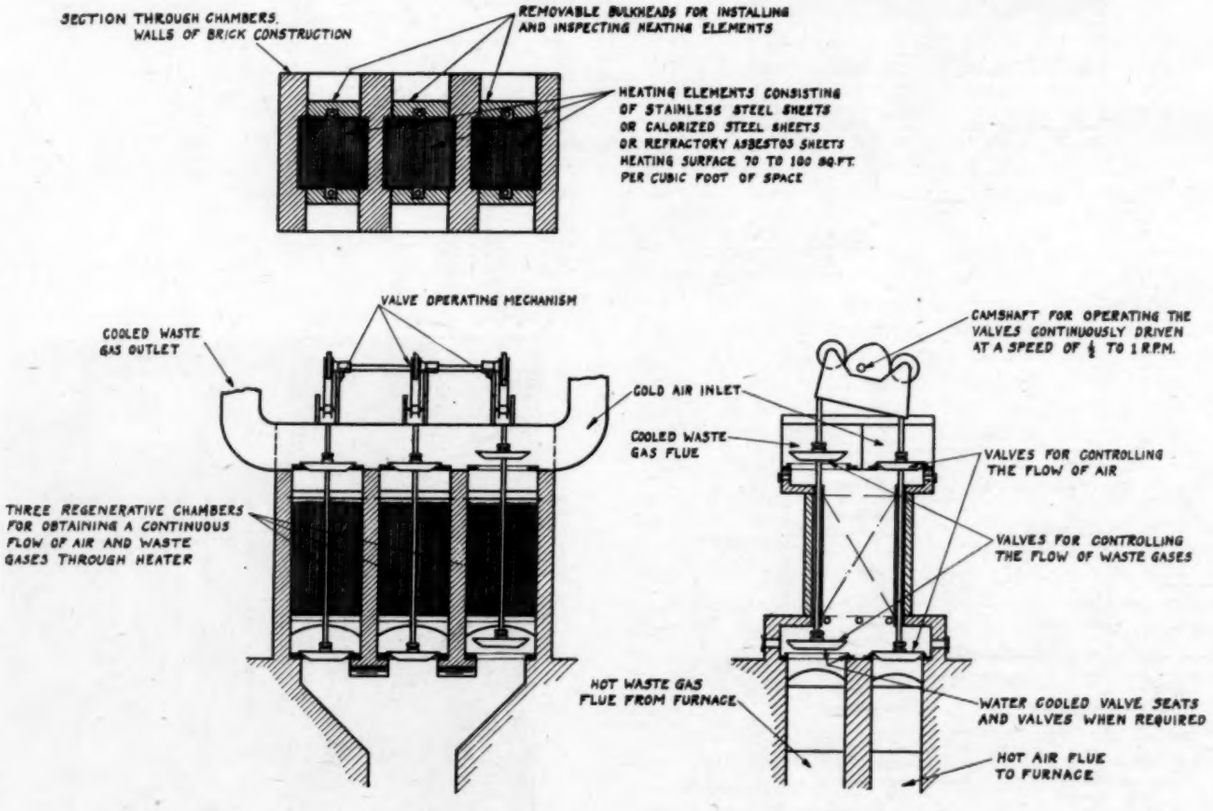
FIG. 4

gases that can be handled by this heater is about 170,000 lbs. per hour. For still higher capacities it is planned to make a five-chamber unit, which by proper valve lifting arrangement, will have twice the valve openings as the three-chamber unit. This heater will have the same height and width, but will be 32'8" long and will have a maximum capacity of about 276,000 lbs. of air and 340,000 lbs. of waste gases per hour. These heaters are capable of heating the air to within 125 to 150° F. below the temperature of the waste gases entering the heater in boiler practice at the maximum capacity.

Some of the advantages of this heater are that any deterioration of the heating elements does not affect the working and only to a slight degree the efficiency of the heater and deposition of soot does not cut down the efficiency nearly as much as in ordinary air heaters and the heater is very easy to clean either by permanent soot blowers arranged in top and bottom or in the center of the chambers, or by steam nozzles introduced through the cleaning holes. The steel sheets are also comparatively inexpensive and can easily be changed. It is also possible to regulate the spacing between the plates to suit local conditions and to use the most suitable metal, such as stainless steel, cast iron, copper, brass or various kinds of non-metallic materials for heating element.

The heater can also be adapted for high temperatures, as shown in Fig. 5. For all hot parts of the heater brick walls are substituted for steel plate and valve seats and valves are water-cooled where necessary. With stainless steel plates such a heater can use waste gases of as high as 1500°F. and can preheat air to 1200°F.

Fig. 6 shows the heater adapted to a small heating furnace. Only a part of the total waste


SECTION THROUGH CHAMBERS. WALLS OF BRICK CONSTRUCTION
REMOVABLE BULKHEADS FOR INSTALLING AND INSPECTING HEATING ELEMENTS
HEATING ELEMENTS CONSISTING OF STAINLESS STEEL SHEETS OR CALORIZED STEEL SHEETS OR REFRACTORY ASBESTOS SHEETS HEATING SURFACE 70 TO 100 SQ.FT. PER CUBIC FOOT OF SPACE
VALVE OPERATING MECHANISM
COOLED WASTE GAS OUTLET
CAMSHAFT FOR OPERATING THE VALVES CONTINUOUSLY DRIVEN AT A SPEED OF ½ TO 1 R.P.M.
COLD AIR INLET
COOLED WASTE GAS FLUE
VALVES FOR CONTROLLING THE FLOW OF AIR
THREE REGENERATIVE CHAMBERS FOR OBTAINING A CONTINUOUS FLOW OF AIR AND WASTE GASES THROUGH HEATER
VALVES FOR CONTROLLING THE FLOW OF WASTE GASES
HOT WASTE GAS FLUE FROM FURNACE
WATER COOLED VALVE SEATS AND VALVES WHEN REQUIRED
HOT AIR FLUE TO FURNACE

BLAW-KNOX PATENTED CONTINUOUS REGENERATIVE AIR HEATER FOR HIGH TEMPERATURES

FIG. 5.

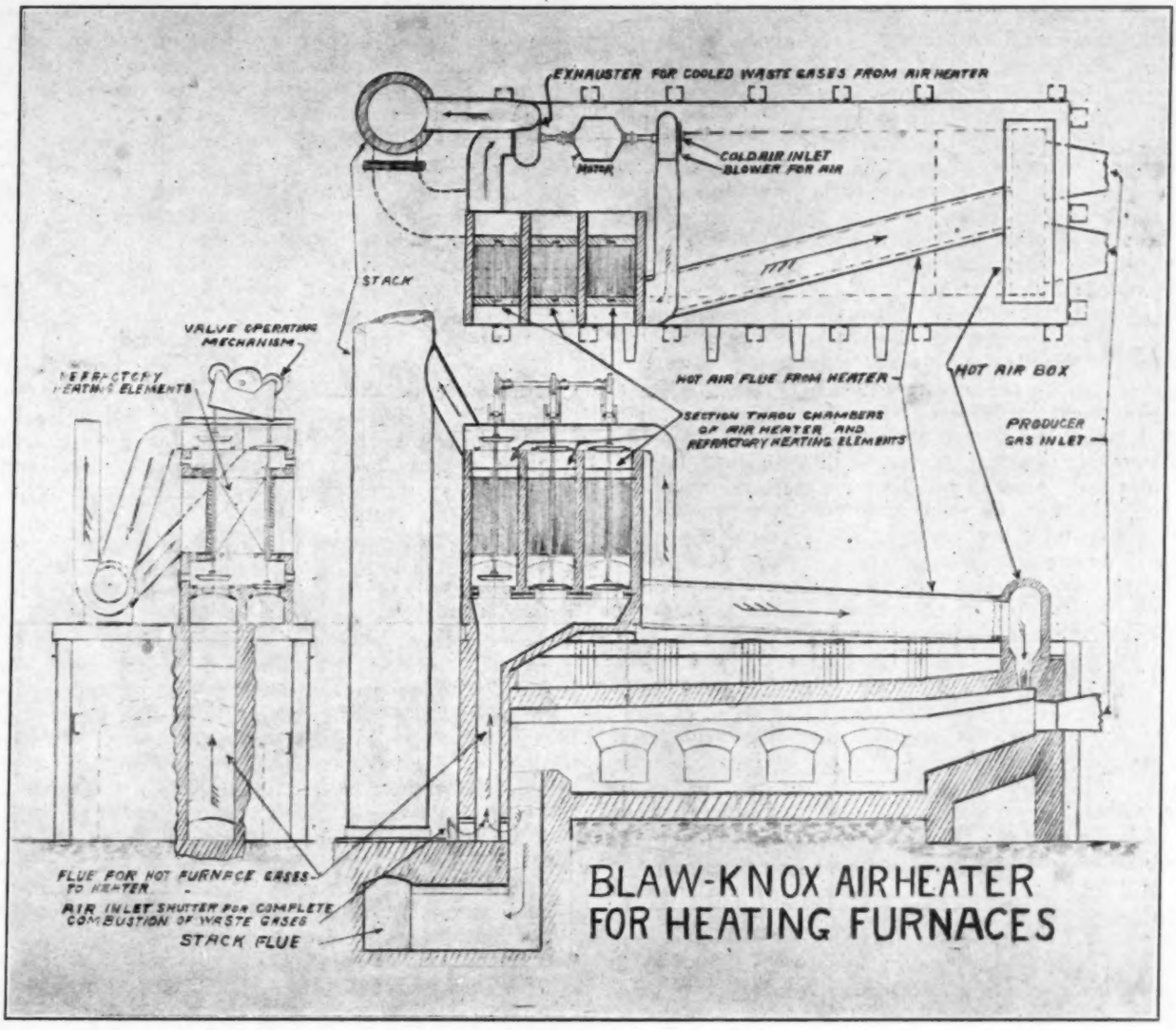

EXHAUSTER FOR COOLED WASTE GASES FROM AIR HEATER
COLD AIR INLET BLOWER FOR AIR
MOTOR
STACK
VALVE OPERATING MECHANISM
REFRACTORY HEATING ELEMENTS
HOT AIR FLUE FROM HEATER
HOT AIR BOX
SECTION THROU CHAMBERS OF AIR HEATER AND REFRACTORY HEATING ELEMENTS
PRODUCER GAS INLET
FLUE FOR HOT FURNACE GASES TO HEATER
AIR INLET SHUTTER FOR COMPLETE COMBUSTION OF WASTE GASES
STACK FLUE
BLAW-KNOX AIR HEATER FOR HEATING FURNACES

FIG. 6.

gases are passed through the heater, as it is not necessary to use all the waste gases for obtaining the required preheat of the combustion air. A heater of this type is so small even with a heating surface of ten to fifteen times the hearth area that it can be placed on top of the furnace, which eliminates expensive digging and foundations which are necessary with most other types of recuperators. A much higher preheat can be obtained than with cast iron pipe or brick recuperators for the same initial cost of installation.

It might in this connection be of interest to compare the apparatus now used in steel works for producing hot blast for blast furnaces—the largest use of preheated air today.

A modern blast furnace producing 600 tons requires about 55,000 cubic feet of air per minute, which is preheated in three stoves of a total volume of about 250,000 and a total heating surface of 200,000 to 250,000 square feet. About 70 millions B.T.U.'s are transferred per hour to the air in these stoves. This is not more than is transferred in an ordinary 1000 H.P. boiler running at 200 per cent rating, occupying a volume of about 8,000 cubic feet or about 3 per cent of the stove volume. Of course, the conditions of heat transfer are different, but the comparison is not without interest just the same and it does not look impossible at all to me to construct an air-heater on somewhat the same lines as the heater described which would do the same work as the blast furnace stoves and which would occupy only about 10,000 to 12,000 cu. feet, or four to five per cent of the stove volume.

This may seem to a lot of us an entire impossibility at the present time, but when we consider the tremendous increase in efficiency of apparatus in all technical fields in recent times, we should hesitate to say that it is impossible. Who would have thought, for instance, thirty years ago, that we could build a combustion engine weighing less than two pounds per horse power? Or who would have predicted that we could build a single steam turbine unit of 60,000 kilowatt capacity? There are only a few examples of the tremendous steps that have been taken and are being taken at the present time for increasing the efficiency of apparatus and of material in general with which we have to work, as well

as of the human efforts required in using and directing modern machinery.

Geo. A. Orrok*: Preheaters are very old. They go back a hundred years; they have been used practically continuously for a hundred years. The Howdens system and the Ellis-Eaves system have been used sixty years on ships, and, to some extent, on land—and very satisfactorily. It is onyl during the last three or four years we have been hearing aobut air heaters in order to save the last few per cent we thought was going up the stack. Air heaters can only save that percentage that goes up the stack plus a very little more, of small moment, in combustion; how much more nobody knows at the present time. We do know that a boiler operating at 45% efficiency can add about 50% to its efficiency, bringing it up to 67% if it puts the Howden system on. A boiler running at 88% efficiency can probably add one-half of one per cent to its efficiency by the use of an air heater; and that no matter how much surface you use—because your flue gases only contain about four per cent of the total heat in the coal. The amount you can save from that is comparatively small. There must be some sensible heat in the gases going up the chimney; and your moisture loss will always go up the chimney—the heat from hydrogen and the moisture of the coal. But if you run below the dew point in your gases and your heater goes to pieces in a short time.

As to the method of calculating air heaters, it depends on whether you take an ordinary tubular boiler and put an air heater on it, or one with economizers.

Back in 1881 Mr. Hoadley tested a return tubular boiler in the Pacific mills with an air heater. Without the air heater he got eighty-one and a fraction per cent efficiency; with the air heater he got eighty-two and a fraction per cent. The air heater was a tubular heater and very carefully made; and his return tubular boiler had a setting that was very good indeed, and Mr. Headley did most of the firing himself—which was responsible for the very good efficiency obtained. He was one of the best engineers this country has produced.

I was reading the other night about some tests that were made on a marine installation in about 1860, where, as I say, the boiler efficiency was increased about 50%—from about 40% to 60%. I think you have between those two percentages to work on with your air heater.

There is one other point. Remember, that of your total heat used in the cycle you waste out of the condenser—on a general average, around 55%—the heat that goes up the stack is anywhere from four to sixteen per cent, or even higher.

M. D. Flanders† I would like to add a word. This is not directly in my line, but I have had experience with boiler operation; and it seems to me the question of air pre-heating cannot be divorced from the question of feed-water heating. As Mr. Orrok pointed out, the boiler with superheaters and modern stokers, can be improved about five or ten per cent in efficiency by the use of economizers, but if you don't have economizers, and do all the feed heating by abstraction from the main turbine, it becomes a question for air-preheating—and instead of one or two per cent, there is possibly five or ten per cent further gain by not using the economizer, and installing the air preheater.

As I see the problem, you have two main sources of waste—heat going up the stack and heat going out with the circulating water in the condenser. Dam them up and get the heat back as soon as you can. The easiest way to keep it from going into the circulating system is by feed heating and preheating. Let the feed water keep the heat out of the circulating water and let the incoming furnace air keep the heat out of the flue gases.

How much you can check in feed water heating will depend on the design of the plant aud turbines, et cetera. So I want to say my word—that the problem is not one you can give any general answer to. It is to be taken up in the specific case, keeping in mind these two main losses. The two have to be considered together.

P. T. Vanderwaart‡: I am interested in the subject primarily from the application engineer's standpoint, and I hope that we will have some discussion on the economics of the subject. Each application must be considered on its merits, and the probable relation between efficiency and per cent rating must be determined by a series of "cut and dry" calculations. For the combustion of fuel at any given rate and most reasonable excess air, assume the most probable degree of preheat and determine the products of combustion from operating characteristics of stoker and setting. From operating characteristics of the heating surface of boiler under consideration determine the temperature of gas leaving boiler. From operating characteristics of preheater determine amount of preheat, which should check the first assumption.

From the curves given in the paper, we learn that in the case of modern underfeed stoker, boiler and superheater, without economizer and without preheater, we can expect 83% efficiency at 200% rating and 74% at 500% rating. With preheater expect 365°F. air in wind box and 90% efficiency at 200% rating and 500°F. air and 82% efficiency at 500% rating.

When the comparative efficiencies have been worked out, it is a simple matter to determine whether or not the expense of the air preheater is justified.

Much has been written on the general subject of preheaters, mostly descriptions of particular heaters, their installation and the operating characteristics of the heater itself. Numerous test results are available on the operation of boilers equipped with air preheaters. These test results, however, deal with overall efficiency and practically no data is given to determine to what extent the preheated air is affecting the particular efficiency of grate, furnace and heating surface.

The effect of preheated air on reduction of carbon in residue, improvement in combustion and increased transfer of heat to boiler heating surface are factors which will be investigated very carefully by the engineer considering the application of an air preheater in an existing boiler plant. The case

*Consulting Engr., New York, N. Y.

†Engr. Westinghouse Electric & Manufacturing Co.

‡Elec. Engr., New Jersey Zinc Co., Palmerton, Pa.

for the preheater will be materially advanced by giving more publicity to the quantitative values of these factors for the several kinds of fuel, grates and settings.

J. G. Worker: It seems to me that you gentlemen, as engineers, will have to determine in your own minds the question as to whether or not preheat will pay for a specific situation. I have shown you in this paper the thermal efficiency of a stoker unit using ordinarily cold air and this same stoker unit using preheated air. This is for a particular situation. Now, if you require specific information for your own particular problem, something will have to be known about the coal to be used, the gas temperatures, gas velocities, etc. When you have all of this data for a specific case, the problem becomes simple.

We did ask a preheater manufacturer to work out a particular case in which three different air preheaters for the same boiler were considered.

Case one has an air preheater of 6,500 sq. ft consisting in plates 5'x10'.

Case two has an air preheater of 6,500 sq. ft. consisting in plates 5'x15'.

Case three has an air preheater of 13,000 sq. ft. consisting in plates 5'x15'.

It will be evident that Case One will recover less heat units than Case Two, which has longer plates, but at the same time the power consumption for Case One will be less than for Case Two. It may be assumed that the prices of these two heaters are identical. Case Three uses a longer plate, but has exactly half the gas velocity of Case Two. The heat transferred per square foot will be less. The total heat transferred will be greater. It may be assumed that the price will be double that of Case One or Case Two.

The choice of an Air preheater must take into consideration the credit of heat recovery and the debit of power charge due to resistance, and fixed charges based upon the price. This is assuming that the cubical content of the boiler house would not be varied in either case. Although, of course, this is not always so.

The basis of all calculations are as follows:

For Case One the conditions of operation will be as follows:

Conditions of Operation—6,500 sq. ft. Heater—5'x10' Plates				
Per cent of rating	150	175	200	250
Wgt. of coal burned per hr.	3,720	4,400	5,100	6,520
Calorific val. coal B.T.U. per lb.	13,000	13,000	13,000	13.000
CO_2 content of flue gases	13%	13%	13%	13%
Lbs. of flue gas per hr.	55,800	66,000	76,500	97,800
Lbs. of air per hr.	50,700	60,000	69,500	88,800
Temp. gas entering preheater	525°	550°	575°	625°
Temp. air entering preheater	70°	70°	70°	70°
Temp. gas leaving preheater	320°	330°	350°	395°
Temp. air leaving preheater	295°	300°	310°	315°
Resis. to passage of gas	0.25"	0.3"	0.4"	0.65"
Resis. to passage of air	0.25"	0.3"	0.35"	0.65"
Min. econ. of fuel obtained	6.4%	6.85%	7.05%	7.2%
Per cent of heat recovered	45	45	49	41.5

For Case Two the conditions of operation will be as follows:

Conditions of Operation—6,500 sq. ft. Heater—5'x15' Plates				
Temp. gas leaving preheater	285°	305°	325°	365°
Temp. air leaving preheater	325°	330°	335°	345°
Resis. to passage of gas	0.45"	0.65"	0.8"	1.45"
Resis. to passage of air	0.4"	0.6"	0.75"	1.40"
Min. econ. of fuel obtained	7.45%	7.6%	7.7%	8.1%
Percent of heat recovered	52.5%	51%	49.5%	47%

For Case Three the conditions of operation will be as follows:

Conditions of Operation—13,000 sq. ft. Heater—5'x15' Plates				
Temp. gas leaving preheater	255°	270°	290°	320°
Temp. air leaving preheater	355°	365°	375°	390°
Resis. to passage of gas	0.16"	0.2"	0.3"	0.45"
Resis. to passage of air	0.19"	0.23"	0.32"	0.55"
Min. econ. fuel obtained	7.6%	8.5%	8.75%	9.4%
Per cent of heat recovered	59.4%	58.3%	56.5%	56.5%

In order to arrive at the most economical preheat for this installation we have figured approximately the return on the investment in the following manner. Assuming 175% of rating as the normal load:

	Case 1	Case 2	Case 3
Economy in fuel burned	6.8%	7.6%	8.5%
Economy in dollars per yr.	$6,500.00	$7,125.00	$8,100.00
Approx. H.P. consumed from passage of gas to passage of air	5	11	5
Fixed charges at 15%	$ 845.00	845.00	1,560.00
Cost of power for 7,200 hrs. at $.01 per kw. hr.	$ 360.00	792.00	360.00
Total charges	$1,205.00	1,637.00	1,920.00
Net saving	$5,295.00	5,488.00	6,280.00
Cost of preheater	$5,625.00	5,625.00	10,400.00

From these figures either of the 6,500 sq. ft. preheater pays a larger return on the money invested. The figures of 15% fixed charges and $.01 per electrical H.P. we have chosen as a more or less average value.

From the above you will notice that the cost of the 13,000 sq. ft. heater is not quite double that of the 6,500 sq. ft. heater.

We would like to mention that the economies listed above are based purely upon calorific return of heat. In addition, there is the economy due to improved conditions of combustion, and a reduction in the amount of combustible in the ash and the more rapid transfer of heat to the boiler tubes due to an increased furnace temperature.

*Discussion: Auxiliaries and Auxiliary Drives for Steam Electric Generating Stations**

R. A. Hentz†: In reading the paper, one cannot but be favorably impressed with the importance placed upon reliability. I think those of us who design and operate central stations will heartily agree with that statement. Last year the N. E. L. A. made a survey of various methods of driving power station auxiliaries, and the consensus of opinion of the various companies contributing to that investigation was that reliability is the most important fac-

*Paper presented at Twentieth Annual Convention.

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tor to consider. The extra cost of a thoroughly reliable system over one that is only partially so is but a small percentage of the plant investment, but may make a tremendous difference in its continuity of operation.

Different designs of generating stations and different local conditions may indicate different ways in which the station auxiliary system should be laid out and consequently a number of different schemes have been used by central stations throughout the country. However, there is a unanimity of opinion among engineers as to certain matters. For instance, the particular importance of boiler feed pumps and condenser circulating pumps. In practically all plants these two auxiliaries are laid out so that practically no interruption to them is to be expected. Another feature that is not always stressed as much as this is the station lighting. Whether it is a generating station or a steel mill or practically any other plant where there is moving machinery, the hazard of not having adequate lighting at all times is apparent. A common way of insuring continuous lighting in the generating stations is to arrange for automatically throwing certain selected lighting circuits on a storage battery. This battery is usually provided for emergency excitation anyway, but the importance of lighting is so great that in the opinion of many engineers, the battery is justified on the score of emergency lighting alone.

Next to reliability and closely allied to it is the matter of simplicity, for if a layout of a station is easily kept in mind, the chance of trouble is somewhat decreased and the ability to find it when it does occur very much enhanced.

Of course, the matter of cost cannot be entirely forgotten, and there may be certain cases where some slight increase in reliability would not be justified on account of the heavy cost that this would involve. The matter is, after all, one of engineering judgment, but the significant factor that should always be kept in mind is that reliability is foremost.

So much for general observation on the matter of supplying generating station auxiliaries.

It might be of interest to give some of the high spots of the station auxiliary system in the new Richmond Station of The Philadelphia Electric Company which goes into operation this fall. The first section of this plant, which is designed for an ultimate capacity of 600,000 Kw., is being erected and will house four 50,000 Kw. turbo-generators, two of which are being installed this year. All of the auxiliaries will be electrically driven except one boiler feed pump for each unit, one steam air ejector for each unit and a fire pump. All of the other auxiliaries are divided into two groups: One, the "essential" ones, which include the motor driven boiler feed pumps and all condenser pumps. These are supplied through transformers tapped directly on the generator leads. The other, the "non-essential" (comparatively speaking) auxiliaries. These are supplied through transformers connected to the main bus bars. The idea behind this arrangement is that even though the main bus bars may be dead, the turbine auxiliaries would continue to function from power obtained through the first group of transformers. In the case of the failure of this bank, relays automatically transfer these essential motors to the second group of transformers, that is, those connected to the main bus bars.

Under ordinary conditions, the failure of these transformers connected to the main bus bars would only interrupt those auxiliaries that could stand a short interruption. The boiler fans form the largest part of the load connected to these banks, and when the main bus bars are dead and the station is delivering no load, there is a distinct advantage in having these fans shut down.

In addition to the two groups of transformer banks, the station is provided with a 2000 Kw. house alternator. This unit is normally not run, but can be started very quickly in emergency, and used for driving certain station auxiliaries in the event of other sources failing.

All of the motors of 75-HP and above are 2400-volts. Smaller than this they are 220-volts. In the case of the stoker motors the plan suggested by the authors is followed, that is, they are direct current (250-volts), their supply being obtained through motor-generator sets.

The question of whether the essential auxiliaries should be supplied through transformers connected to the main generator leads or from alternators connected to the end of the main generator shaft is an open one. While some electrical hazard may exist in the former, there is also a mechanical hazard in the latter. It was our feeling that the transformer scheme, all features considered, was the best. In either scheme care must be exercised that the turbine does not overspeed and trip out in the event of heavy short circuit or other unusual conditions.

W. A. Herr:* The authors have covered the field so well I believe it almost impossible to make any comment.

Although it may prove essential or economical to install a certain type of apparatus in a given central station, it does not necessarily follow that this equipment should be adapted for all cases. It is therefore necessary to make a study of the conditions in each case before it will be possible to select the proper type of equipment.

As a matter of interest I will note some of the general features of The Philadelphia Electric Company's most recent central station which is now under construction.

The heat balance cycle will consist of three stages of heating by bleeding the main turbine.

The first stage of heating is accomplished by a closed heater, the second stage by a de-aerator, which is essentially a heater, and the third stage by an evaporator and after heater. All of the above heaters are of the horizontal type.

The de-aerator is somewhat similar to an open heater, has a large water storage space, and is also tied in with the surge tanks. This system has the advantage of being flexible, and insures a supply of water to the boiler feed pumps at all times.

The heater drips are cascaded back from one heater to the next lowest in pressure, and are col-

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lected in the low pressure heater and pumped back into the condensate line.

The turbine glands are water sealed by condensate, which is collected in a receiving tank and pumped back to the de-aerator.

The h.p. heater, evaporator and evaporator condenser are vented into the de-aerator—the de-aerator being vented direct to the atmosphere when the pressure is above .5# G.; and when operating below this pressure it is vented by means of a hydraulic air pump.

The L.P. heater is vented back to the main condenser.

One steam jet and one hydraulic air pump will be installed per unit. The hydraulic air pump will normally be in service.

Each unit will have two condensate and two circulating pumps all of which are to be motor driven.

Two motor driven and one steam driven boiler feed pump will be installed per unit, each motor driven pump being of ample capacity to take care of the main unit. The steam driven pump is for emergency only, and will automatically come into service in the event of a failure of the motor driven units.

The boiler feed pumps take their water direct from the de-areator, and deliver it to the boiler feed header through the evaporator condenser and after heater.

The boilers in this station will have approximately 40 per cent economizer and 160 per cent of preheater surface.

All boiler auxiliaries will be motor driven.

The difference between our equipment and that outlined by Messrs. Penniman and Quarles shows the wide variation in the installation of power plant auxiliaries; and may note, also, that a radical difference can be found when comparing any of the newer large stations.

George A. Orrok:* This subject of Auxiliary Drive in the Central Station is a most interesting one, and has occupied the attention of the designing engineers for a great many years.

We really have two systems of auxiliary drive—the steam drive and the buss drive. As a development of the buss drive we have the house turbine and the so-called heat trap arrangement; and then, in between, we have a great variety of systems which vary from the all-steam, on one side, to the all-buss on the other.

The most efficient auxiliary drive is somewhere in this field. I often say it might be represented by an equilateral triangle, with the steam drive as one side and the buss drive as another, and the heat trap as the third; and somewhere in the triangle you will find the most efficient drive.

Between the three, or any combinations of the three, the difference in economy does not amount to over one per cent. So far as economy goes we may dismiss the question that any particular system is any better than any of the others. One per cent in the economy is something below the limits of error. Your scales are allowed a tolerance of two per cent under the State law.

When it comes to cost, you buck up against a different propostion. Of all the types of drive the steam drive is probably the cheapest, with the buss drive second, while the heat trap plan may be fifty or one hundred per cent higher.

Combinations, however, come somewhere within the lower half of this category. I personally believe that the best results can be secured from a partial steam drive, that is, a steam drive for all essential auxiliaries; and I believe that a station may be designed this way in which the theoretical differences in economy will be within one-fourth of one per cent from the very best of any other system that can be made. In other words, so far as economy goes it is negligible. The cost, however, on a large station, rises greatly. I know of one station where over a million dollars were saved on first cost by using the steam drive for auxiliaries.

Why do I say that from the standpoint of economy the steam drive is the best thing? The most important point for a central station system is reliability. If you search the files of the Electric World for the last three to five years you will read of systems being out for three hours at a time, and being unable to start up during that time; and when you look to find what the cause was, you learn they had electric auxiliaries—no steam auxiliaries in the station. This is not an isolated case; there are a number of others.

Shortly after this one particular accident I refer to happened, a very similar short circuit occurred on a system which had steam auxiliaries. The outage was seven minutes on the high tension side, the units were back, the buss that burned out was isolated, and everything was running in the regular way. There was a portion of the system out for twenty-five minutes, but due to the burning out of a high tension line twenty-five miles away from the station; and while it may be charged to a short circuit of the station, yet it wasn't a station difficulty.

It must be a very poorly designed plant that cannot be put back on the line in seven minutes if they have steam auxiliaries. If you go to electric auxiliaries, and have sufficient reserve, that is, sufficient ways of feeding—for instance, supply from another system, a storage battery, a house turbin entirely separate from the main system, a buss separate from the main buss—then you have an auxiliary capable of doing the same thing as the steam auxiliary.

However, I am still standing on my opinion that the steam auxiliary is reasonably efficient—as good as any—and much more safe and reliable.

L. Hausmann:* There are some power plant engineers in the industrial field, and particularly in the iron and steel industries, who will insist that a greater degree of safety against interruptions in service is obtainable with the use of steam turbine driven auxiliaries than with motor drives, and are quite willing to sacrifice a slight amount in the overall efficiency of the plant to obtain this. The heat balance can be worked out quite satisfactorily with steam auxiliaries, though admittedly not as efficient-

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ly as with the use of bled steam and electrical drives, although should the general trend in power plant practice revert once more to the use of turbine drives for essential auxiliaries, some improvement in plant efficiency could be obtained over that possible at present with steam drives by the use of more efficient small turbines, which manufacturers would no doubt develop should the demands justify it.

Introducing excess low pressure from the auxiliary exhaust lines into the low pressure section of the main unit as described by the authors is quite feasible and has been used in a large number of installations for some time without any difficulty whatever. It is quite standard on a large number of marine installations in which the auxiliaries are almost invariably steam driven. Air is prevented from leaking into the condensing system by the use of a "constant pressure" or "flow" valve. This valve is installed in the auxiliary exhaust line close to the turbine, the design being such that a pressure above atmospheric is always maintained on the side of the valve opposite to the turbine cylinder. These valves may be arranged with counter weights to allow any desired back pressure to be maintained on the auxiliary exhaust lines within the limits of its working range.

The authors feel that one of the disadvantages in the use of small turbines is their lack of reliability with modern pressures and temperatures. Small turbines have been built for a number of years and are in very satisfactory operation using pressures and temperatures encountered in present day industrial and central station practice. Properly designed they can be made to operate with the same degree of reliability as the larger main units. The problems encountered in their design for high temperatures are not nearly as complicated as in the case of the larger units since the designer has to deal with much smaller masses and simpler arrangements.

The authors give but little consideration to the "dual drive." The system of arranging the auxiliary apparatus with both steam and motor drives gives an opportunity for the plant designer to take advantage of the merits of both the electric and steam systems. The main unit may be bled to the fullest extent for feed heating, using under normal operating conditions, the motor for drive, the turbine running idle, its governor so adjusted that it will come into operation at a speed slightly lower than the normal motor speed. Thus, should the source of power, supplying the motor fail, the turbine automatically picks up the load and carries it until the power supply is again established. Sometimes in smaller plants in which the main unit is not arranged for feed heating, the dual drive may be used for obtaining heat balance; the load between the turbine and motor being so distributed as to supply the proper amount of exhaust steam to the feed water heater. The balancing of the load between the two drives can be taken care of automatically by the use of a thermostatic control which regulates the amount of load carried by the turbine. The turbine is protected against over-heating while running idle by the introduction of a very small quantity of steam into the casing through a small orifice. On some designs this precaution is not necessary and the turbines will run idle indefinitely without any cooling arrangement whatever, the radiation from the casing being sufficient to carry away any heat generated.

The authors in the plant layout use two stage air ejectors for the removal of non condensable vapors from the condenser. This is quite standard, although the motor driven hydraulic air pump will sometimes work out more efficiently under certain heat balance arrangements.

The advisability of using condensate for cooling the oil is questionable in a relatively small size installation. There is always present the possibility of the load being suddenly released in which case there would be an insufficient flow of condensate to cool the oil and may result in serious damage to the turbine through failure of the bearings. At very light loads there would also be danger from the same source. An impairment of vacuum, due to air leaks suddenly developing, or from any other cause, would cause a rise in condensate temperature and thus cause a dangerous rise in oil temperature. It would be far more reliable to supply the cooling water from an independent source. A raw water compartment could be used in the cooler, but this would result in additional complications. The same reasoning applies to the use of condensate in the generator air cooler. It is, of course, very nice to be able to recover the bearing and generator windage losses, but in an industrial plant of relatively small size, it hardly pays to do this on the final analysis looking at the problem from the reliability angle.

The use of the so-called "hairpin" type bleeder heater is proposed. One of the advantages claimed for this type is its adaptability for installation in a vertical position and thus facilitate the removal of the tube bundle for cleaning. The floating head type of cooler can be easily adapted for vertical installation and the removal of tube bundles from this position, although there should be no necessity of removing the tubes at frequent intervals.

The authors use a D.C. motor for the stoker drive. This is quite common practice. Recently there has been placed on the market a small turbine especially designed for stoker drive. The turbine is connected to the stoker gear box through worm gearing and is entirely self inclosed. It is equipped with an oil governor similar in design to those used in certain classes of medium sized generator drive turbines. The speed of the trubine is controlled by changing the discharge pressure of the oil governor impeller. This is done by simply manipulating a small crank and any speed range may be obtained between zero and maximum, making it possible to operate the stokers at any desired rating with ease. This type of stoker drive I believe has distinct advantages over the D.C. motor drive. It is manifestly more adaptable for installation in the firing isle than would be a motor.

I believe that additional reliability would be obtained by using a dual drive arrangement on the exciter set instead of the simpler motor drive.

George A. Orrok: May I say one more word? I judge, from the remarks of the last speaker, that my remarks on reliability have been misunderstood. The electric motor is just exactly as reliable a machine as the steam turbine—and the steam turbine as the electric motor. The point I made was that

where you are using the electric motor you have to cut through two links in the chain; if you lose your buss you lose your motor, whereas the main apparatus is running. If you have a steam drive—as long as your steam is going, your machine is going—and your main auxiliary. That is the point.

Everett Eslick*: The authors very properly emphasize the consideration of "Reliability" as being of prime importance in the selection of power house auxiliaries. Lack of the proper consideration of this item has in some cases brought criticism of electric drive for auxiliaries when as a matter of fact the fault was due to improper consideration of the continuous service demanded of the apparatus or unnecessary complication of the parts furnished. In view of this condition, cheap or shoddy apparatus should not be considered competitive with specially designed apparatus which is especially constructed to meet severe operating demands. This last statement would seem to apply particularly to control apparatus.

In regard to the range in speed required in stoker drive, there are a number of large plants operating successfully with a speed range of only 4 to 1. If it is a power station with unusual load conditions, it would require a speed range of the stoker motors greater than 4 to 1. As has been pointed out, the torque of a stoker is quite variable, making a motor with characteristics of the D.C. adjustable speed shunt wound motor especially adaptable for this service, because with this motor the speed for a given shunt field setting is independent of the torque. It is doubtful if the extra expense involved in furnishing enclosed type motors with navy brackets is justifiable for this service. Drop proof motors with special coal dust resisting insulation will withstand the effects of coal dust collections on the windings very admirably. A controller with sixteen speed adjustment-points gives very excellent stoker speed control for a speed range of 4 to 1.

Relative to the application of A.C. wound rotor type motors to forced and induced draft fans, they are well suited for this service. As a rule, however, it is not considered good practice to try to get more than 50 per cent speed reduction by the use of a single motor. Where a speed range of 4 to 1 is needed, a dual drive set consisting of two wound rotor motors, a motor being connected at either end of the fan shaft, has proven to be a very good arrangement. This arrangement permits relatively good performance over the entire range and yet retains the advantage of using a reliable type of A.C. motor for this service. The cost of the two motors, including the extra motor of the set, is much less than double the cost of a single large motor—due to the fact that the small motor for such a set, with 4 to 1 speed range, is approximately one-eighth the horse-power of the large motor. Formerly it was considered good practice to provide a clutch for disconnecting the large motor when the small one was driving the fan, but experience indicates that the extra expense of providing the clutch is unwarranted.

With the auxiliary generator operating on the same shaft as the main generator, it is impractical to operate the auxiliary generator in parallel with the main system continuously—due to a difference in phase angle between these generators. However, it is desirable to so construct the auxiliary generator so that it will be able to withstand the extra stresses incident to parallel operation with the main generator during periods of transition from one source of auxiliary power to the other. This parallel operation has been provided for, over short periods, in some of the recent central stations using shaft generators.

It is not apparent to me why a variable speed motor is chosen for the hot-well pump of this station. It would seem that a constant speed motor would be satisfactory, and it would have the advantage of requiring a smaller and simpler controller.

The claim that ball or roller bearings are superior to the sleeve type is an open question. At the present time very few users are willing to pay the higher price for ball or roller bearings; and, furthermore, when a failure of either of these types occurs it is a more serious matter to replace than in the case of sleeve bearings. It should be borne in mind that a stock of replacement ball or roller bearings for the auxiliary rotating machines of a present-day power plant would necessarily be large and expensive. On the other hand, if replacement bearings are not carried in stock, a bearing failure might cause several weeks' outage of a machine, due to the fact that some of the larger size bearings are not manufactured in this country; and it would, therefore, be necessary to wait till shipment could be made from an outside factory. Even then it would be found in some cases that the bearing would have to be made up special, due to the present lack of standardization for anti-friction bearings.

It is true that some of the sleeve bearings used in the past have given trouble. This trouble has been due in some cases to improper lubrication or to the lack of proper maintenance, and in some other cases to faulty design. A properly designed sleeve bearing, on which the proper lubricant is used, and for which a reasonable periodical maintenance program is followed, will give satisfactory performance. This claim is borne out by the fact that a 3600 RPM motor equipped with sleeve bearings has operated continuously, twenty-four hours a day, for the past two years, on a special sleeve bearing test, with the original oil; and down to date no trouble has developed, so the test is being continued.

So that, while the authors of this paper appear to have had experience that makes them believe the ball or roller bearings should be used exclusively, I know of others who have had experience with anti-friction bearings which convinced them that sleeve bearings should be used exclusively.

In conclusion, I want to make it clear that I am not condemning anti-friction type bearings for all applications, but I do not believe that these bearings have been sufficiently standardized, or have been produced cheaply enough up to this time to warrant their use on essential power-house auxiliaries where a bearing failure might mean serious delay. Thousands of motors equipped with sleeve bearings have given entire satisfactions for years, and whenever replacements are necessary they can be made quickly and at a relatively small cost.

*Engr., Westinghouse Elec. & Mfg. Co.

Items of Interest

The Gas Products Association, Chicago, Ill., has issued a four-leaf pamphlet, containing the standardization of Hose connections for welding and cutting torches and regulators. These standards were developed by the Standardization Committee of the Gas Products Association and approved by the International Acetylene Association and the Underwriters Laboratories, Inc.

Thomas Topics for October, contains some very interesting topics. The Clay Thrower by the Pioneer is a very interesting and instructive article. A description of one of the oldest and yet dependable methods used in the present day manufacture of High Tension Bushings is worth a postal card to Grandon E. Eckert, Editor, The R. Thomas & Sons Company, East Liverpool, Ohio.

The Hyatt Roller Bearings Company, Newark, N. J., has just issued a new bulletin number 1559. Its purpose is to explain briefly and clearly the method of selecting the correct Hyatt Bearing for any given installation in Industrial equipment. This bulletin is a valuable and time saving help to both present and prospective users of Hyatt Bearings. Mr. H. M. Carroll, with the Hyatt Roller Bearing Company, will be glad to furnish you with a copy upon request.

The Chicago Fuse Mfg. Co., of Chicago, Manufacturers of Union and Gem fuses and Union Outlet and Gem Switch Boxes, have moved their Detroit office from the Transportation Building to 429 Wayne Street.

The Crocker Wheeler Company, Ampere, N. J., has been changed to Crocker Wheeler Electric Manufacturing Co. This change was effected November 1 of this year.

The Trumbull Electric Mfg. Co., Plainville, Conn., announces a new product, Circle T. Residence Panel Boards. General specifications and description of these boards is covered by Catalog page 168-A.

The Allis Chalmers Mfg. Co., Milwaukee, Wis., has issued a bulletin No. 1132, which relates to Roller Bearing Motors. The Catalog describes the polyphase induction motors with cast steel frames and Timken Tapered Roller Bearings.

The October number of Power Grams, a house organ issued by the Alabama Power Co., contains a very interesting article about a monthly Safety meeting, at which time the "Line Gang" gave a Safety drama. The plot of the skit told the story of a safe workman who had been sent up a pole to work on a transformer, but who was called away by his foreman before he finished making his surroundings safe with the equipment furnished by the company. An unsafe workman was told to complete the work and was thoroughly warned that all the protectors were not in place and should be properly installed. With the usual braggadocio of the ignorant or careless workman, he disclaimed any need of safety devices and attempted to do the work without them. Of course, he was knocked cold and had to be rescued from the pole.

While the doctor was on his way the injured man was given artificial respiration. When the physician arrived in an ambulance the unsafe workman was placed on the usual stretcher and with one of his fellow workmen continuing to give him artificial respiration he was carried away to the hospital. The diminishing clang and roar of the ambulance made a fitting finale to the tragedy.

Among the properties used were a fully equipped Transformer pole, an ambulance, batteries to produce a realistic flash, and the usual safety equipment and the tools of a line gang.

The Alabama Power Co. and the Dixie Construction Co. have offered cash prizes to the three linemen of their respective companies who prove themselves most efficient in solving a series of fifty questions relating to the safe performance of line work.

The test questions are selected from a number of practical problems and are numbered from 1 to 50 as follows:

1. In undertaking a new job, what inspection would you make first?

2. Where you are one of two linemen assigned to a high voltage job, do you consider it important that both know how to resuscitate?

3. What precautions would you take in storing poles temporarily in roadways and highways?

4. In the erection of poles, what precautions does your Company take to prevent accidents: (a) To employee? (b) To street and highway traffic?

5. What inspection should be made by a lineman before climbing a pole?

6. What precaution should be taken in connection with the removal of wires and poles?

7. Why is it necessary to keep all live wires, tools and equipment clear of the roadway, street or highway?

8. What action would you take if you noticed a bad line condition while you were either on or off duty?

9. What precautions should be taken while crossarms are being raised or lowered?

10. How should insulators be handled: (a) On the truck? (b) While they are being raised or lowered?

11. Why should insulators be carefully inspected before they are installed?

12. What precaution should a lineman take in selecting his working position?

13. What should be done with tools while they are not being used aloft?

14. How would you rescue a person who has received an electrical shock on a line?

15. What precautions should be taken in stringing wire?

16. Why is it necessary to have a splice thoroughly dry before solder is applied?

17. When should "grounds" be applied; and how should they be attached?

18. What precautions are necessary in applying ground chains?

19. How should grounds be removed?

20. What precaution should be taken in stringing guy wire?

21. What precautions are necessary where guys are attached to trees?

22. Describe the method used by your Company in installing transformers; mention the safety precautions which are taken in raising or lowering transformers.

23. What precautions should be taken in the storage of line tools and hardware on a track?

24. Where the raising or lowering of tools and hardware would be dangerous to street traffic, what precaution would you take to protect this traffic?

25. (a) Why is it dangerous to use tools having loose or "mushroom" heads? (b) What steps would you take to have them repaired?

26. Why should all tool handles be maintained free of splinters?

27. What precautions would you take in handling ladders: (a) To prevent them from slipping? (b) To prevent them from falling? (c) To protect highway or street traffic?

28. What is the object of a canvas tool bag?

29. Mention the care you would take in the use of solder?

30. What rubber protective devices would you carry on a line truck?

31. Why are rubber gloves necessary?

32. How and when are rubber gloves tested on the job?

33. How are rubber gloves stored?

34. How should wet rubber goods be handled?

35. Consider a heavy pole on your system; suppose that you had to work on one of the high-voltage wires; explain fully how you would protect yourself; what kind of portable protective insulation would you use and how would you apply it? (A small sketch of the pole and application of protective insulation should be shown.)

36. Why and when do you examine your safety belt?

37. Why should the use of metal parts on the body belt be avoided?

38. Why is it necessary to use long gaffs on your climbers, and why should they be maintained sharp?

39. When should climbers be used?

40. When should climbers be not used?

41. Why should no metal parts be used in the construction of hand lines?

42. Why is it necessary to use only dry hand lines?

43. Why should hand lines be kept free from solder, oil and grease?

44. Why is it dangerous for linemen to wear rings while working on any kind of electrical equipment?

45. Why should a lineman avoid the use of metal buttons, wire or metal in his clothing?

46. What precautions are necessary in the operation of disconnect switches?

47. Explain the steps you would take before beginning work on oil switches.

48. Why is it necessary for each line crew to make its own request for a high-voltage circuit and to provide for its own protection?

49. Why is it necessary that only one representative of a line crew make all arrangements for the clearance and connections of all high voltage lines or equipment which is being repaired?

50. Why is it necessary to repeat each telephone instruction?

Materials Handling by the Westinghouse Elec. & Mfg. Co., under motor Applications Circular No. 7378, is a most unusual and attractive treatise covering Material Handling. The purpose of the publication is to treat the general subject of Handling materials. The table of contents is as follows: Introduction, Handling materials by modern methods, Cranes, Hoists and Winches, Conveyors, Coal Loading Machines, Freight Elevators, Trucks and Tractors, Locomotives and Larry Cars, Coal and Ore Bridges, Coal Towers, Unloaders, Car Dumpers, Excavating Shovels and Drag Lines, Dredges, Aerial Tramways, Motors and Control, Installations.

The Carbon Electrode, third edition, by the National Carbon Co., has just been distributed to the trade. The history of the development of the Carbon Electrode and the Electric furnace is of interest to every Electric Furnace user. A copy of this book may be obtained by writing the National Carbon Co., Inc., New York, N. Y.

The Pittsburgh Electric Furnace Corporation, Pittsburgh, Pa., has issued a very handsome 70-page book describing the Moore Rapid Lectromelt furnace for Iron and Steel Melting. This book is profusely illustrated with pictures of Moore Electromelt Furnace installations. An interesting paragraph in this booklet under the signature of Mr. W. B. Wallis, President, is that in 1913 there were only 19 steel making furnaces in use in America. This number increased steadily until at the present time there are more than 1,200 Electric furnaces in operation throughout the world making various grades of Iron and Steel. Some of the subjects covered are Steel castings, Gray iron, Steel ingots, Special applications of the Lectromelt, Lectromelt design, and Special Lectromelt furnaces.

The American Engineering Company, Philadelphia, Pa., has issued a 65-page booklet describing the

Taylor Stoker. One of the interesting articles is the New Records for Boiler Furnace Efficiency and capacity established at Hellgate station of the United Electric Light and Power Co. Many important developments originated in the Taylor Stoker are described in detail.

The Ladd Water Tube Boiler is described in detail in catalog number 23, just issued by the George T. Ladd Company, First National Bank Bldg., Pittsburgh, Pa. This boiler has been developed to meet requirements of heavy duty and sustained overloads and the design combines economy of operation and a small expense of upkeep with a great adaptability to all combinations of size, grade of fuel, pressure, overload capacity, superheat and space requirements. Interesting data is furnished in connection with details of construction, drums, feed box, baffling, doors, suspension, dutch oven type, high arch type, Three drum type, multi drum type. Waste heat boilers, four drum type, preheater or Integral Economizer, Brickwork, Efficiency and Upkeep. Copies furnished upon application.

The Erie Malleable Iron Co., Erie, Pa., presents to the Electrical user the story of the Emico Kondu-Box. The purpose of this booklet is to acquaint the trade with the Emico Kondu-Fittings and a few of its many labor and cost saving features. A card to Mr. R. P. Dunmire, Gen. Mgr., will place this interesting booklet on your desk.

"C-H Magnetic Clutches" is the title of a new attractive sixteen-page book, published by The Cutler-Hammer Mfg. Co., of Milwaukee, Wisconsin. This book, which is known as Publication P-11, illustrates and describes many uses for these clutches on synchronous motor drives where the starting is severe, such as in cement, flour, paper and steel mill industries. It contains much working data and describes the principal features of the C-H Magnetic Clutch, which may be summed up as follows:

Ease of operation, direct magnet action, smooth acceleration, no end thrust, fixed capacity, simplicity, low maintenance cost and the advantages of its use with standard synchronous motors.

An automatic change-over switch, designed to give continuity of service, and thus eliminate the serious losses occurring from the failure of voltage in such places as banks, hospitals, stores, laboratories, etc., is described in a leaflet recently released by the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pa. This publication outlines the construction, application and distinctive features of this switch which is essentially three-pole, double throw, full automatic oil circuit-breaker with a low voltage release.

An important development in the field of power transmission machinery has just been announced by the Allis-Chalmers Mfg. Co., who have recently perfected an entirely new type of short center, flexible drive, known as the Texrope Drive.

The Texrope Drive consists of two grooved sheaves and a number of specially constructed endless "V" belts. The sheaves are set just far enough apart so that the belts fit the grooves without either tension or slack.

Previously no short center drive existed which did not have slip, back lash or lost motion, which caused jerky starting and uneven running. Since the Texrope belts just fit the sheaves, there is no slack or lost motion in the drive. Because of the "V" construction, they cannot slip, as the harder the pull the more firmly the belts grip the grooves. Being elastic and stretchable, they cannot jerk, either in starting, acceleration or running, nor can they transmit vibrations, but act as cushions between the driving and driven machines. Therefore smoothness of transmission never attained before is delivered by the Texrope Drive, as opposed to the series of linear pulsations delivered by the ordinary short center drive.

Bearing pressures are low, since no belt tension is employed. The drive occupies very little space. It is silent, perfectly clean, unaffected by moisture or dirt, and is safe, simple and trouble proof. Since there is no slip, the speed ratios are fixed and exact. It is durable, and each belt carries its proportional share of the load.

Texrope Drives from ½ to 250 HP, with ratios up to 7 to 1 and belt speeds from 800-6000 feet have already been placed in service. They have been applied to nearly every industry, notably textile machinery, fans and blowers, machine tools, food manufacturing machines, refrigeration, mining, crushing, wood and metal working machinery, elevators and conveyors, paper, flour and rubber mill drives, etc.

Arc welding has been used at the several works of the General Electric Company for several years past with marked success. Its introduction has been responsible for a change in design of some of the lines of apparatus whereby the use of arc welded boiler plate has been substituted in place of cast iron. In a great many cases, electric welding has taken the place of gas welding effecting considerable saving. It is a matter of interest to note that in one of our factories, in 1913, we were using twelve arc welders on thin sheet steel (1/16" and 3/32") transformer tanks. The seams were welded by means of carbon arc, there being no metallic electrode holders employed at that time. Today the same factory is using 57 arc welders, fifty-two using metallic electrode and five using carbon electrode.

Each month they consume more than one thousand carbon pencils, 13,500 lbs. of welding wire, 40,000 Kw. hours of electrical energy and do 67,500 feet of welding.

The following are the different lines of apparatus on which arc welding is being used:

Transformers, Locomotives, Motors, Pole Piece Assembly, Commutator Shells, Motor Bases, Motor Fields, Terminal Boards, Generator Stator Frames, Oil Pans, Oil Circuit Breakers, Miscellaneous Tanks, Miscellaneous Structural Iron, Cast Iron and Steel Castings, Miscellaneous Shop Equipment, Switch-

board Supports, Furnaces, Mercury Boiler, Arc Lamps, Rectifiers, Compressors, High Pressure Oil Pipes for Turbines, Building up Shafts, Copper Hydrogen Brazing Furnaces, Wire Enameling Machines, Flow Meter Nozzles, Jigs and Fixtures.

As a general observation gained from our experience in the making of tight joints and seams, such as are required in a great deal of our work, we have found that arc welding is about 15% cheaper than riveting and about 20% cheaper than gas welding.

In the welding of thin sheets up to 1/16" the cost of gas welding is not any higher than arc welding, while for thicknesses greater than 1/16" arc welding is a great deal cheaper.

Satisfactory oil-tight seams cannot be made in steel much thinner than 1/8" by riveting. Riveted seams in this thin steel are usually soldered or a gasket is employed to guarantee a tight joint. With the electric arc this is not necessary.

Thomas Franklin Manville, Chairman of the Board of Directors of Johns-Manville, Incorporated, died at 6:45 P. M. Monday, October the 19th, 1925, in New York City. Mr. Manville was one of the country's great business builders. For the past twenty-five years he has been the directing head of Johns-Manville, Incorporated, the world's largest producers and manufacturers of Asbestos, during which time he has built up an outstanding organization fully capable of carrying on his plans and policies to even greater achievements. His brother, H. E. Manville, who succeeded to the Presidency of Johns-Manville, Incorporated, in 1924, was closely identified with him during this entire period and will continue to direct the policies of the organization.

In addition to Chairman of the Board of Directors of Johns-Manville, Incorporated, the late Mr. Manville was President of the Arizona Asbestos Company, Treasurer and Director of the Asbestos Wood & Shingle Company, President and Director of the Canadian Johns-Manville Company, Director of The Fibre Corporation, Director of the Fifth Avenue Bank, Trustee of the Franklin Savings Bank, President of the Board of Trustees of the Fifth Avenue Hospital, and President and Director of the Manville Securities Company. He was a member of the Bankers, Metropolitan, and Union League Clubs in New York City.

The Roller-Smith Company, 233 Broadway, New York, N. Y., announces that its Knoxville, Tenn., agent, The Tennessee Engineering & Sales Company, has opened a branch office at 493 No. Boulevard, Atlanta, Ga., and all Georgia business will be looked after from the Atlanta office.

The Roller-Smith Company announces also that its New England agent, The Detweiler-Bell Company, now has its main office at 101 Milk Street, Boston, Mass., and has a branch office at 152 Temple Street, New Haven, Conn. Mr. Paul G. Detweiler and Mr. R. H. McCormick are located in the Boston office, and Mr. F. M. Lord is in the New Haven office.

PRINCIPLES OF SALESMANSHIP

(Continued from Page III)

action should produce a profit to the seller and satisfaction to the buyer.

Second Principle: Any article to be honestly salable must contain all the factors of sale, which are, attractiveness; utility; specific merits; adaptability to customer's requirements; and conformity of price to merits and use.

Third Principle: To assure the salableness of an article, its factors of sale must be shown to be in conformity with the apparent requirements and natural characteristics of the customer.

Fourth Principle: The logical demonstration of the presence of all factors of sale in an article, plus the customer's comprehensiveness and ability to buy, equal the making of a sale.

Fifth Principle: The price of an article of sale is secondary to the proper presentation of its merits, and of its adaptability to the customer's requirements.

Sixth Principle: In the making of a sale, the customer's mind must be made to assume the attitude of attention, interest, desire, and conviction, in the order named; and this is what constitutes the **Mental Law of Sale.**

Seventh Principle: The number of sales resulting from the properly directed efforts of the salesman will be in proportion to the number of accessible persons in a given territory to whom the goods are adaptable.

Eighth Principle: To assure the gaining of attention, the salesman's approach to the customer must be made in a manner which places him on a basis of equality with the customer, as seller and buyer, without manifesting undue familiarity.

Ninth Principle: Before the mind can become interested in an article of sale, the attention must be firmly fixed upon it in a **willing** manner.

Tenth Principle: Desire for an article of sale can result only when the customer's feelings have been aroused to an appreciation of the adaptability of the article to his requirements.

Eleventh Principle: The mental conviction to buy an article can result only when the mind is satisfied that the making of the purchase will satisfy or gratify a particular need or desire without material injury to the mental comfort of the buyer.

Twelfth Principle: The closing of a sale depends upon the ability of the salesman to offer the proper suggestion to the customer at the psychological moment, which results from the perfect union of the reason with the emotions.

New Readers of the Iron & Steel Engineer

C. L. BAKER,
Management's Rep.,
Bethlehem Steel Co.,
Johnstown, Pa.

J. L. MILLER,
Steam Engineer,
Wheeling Steel Corp.,
Wheeling, W. Va.

JACK C. PHILLIPS,
Sales, Engr., Crouse Hinds Co.,
Philadelphia, Pa.

C. A. HAUSMAN,
Salesman, Crouse Hinds Co.,
Syracuse, N. Y.

A. J. DREYER,
District Manager,
The Harnischfeger Corp.,
Farmers Bank Bldg.,
Pittsburgh, Pa.

T. E. BEDDOE,
Branch Manager,
The Cutler Hammer Mfg. Co.,
1201 Chestnut St.,
Philadelphia, Pa.

E. H. McNEILL,
Sales Engr., The Okonite Co.,
310 S. Michigan Ave.,
Chicago, Ill.

C. F. PITTMAN,
Ind. Dept., General Electric Co.,
Schenectady, N. Y.

H. J. MEISSNER,
Dist. Rep., Illinois Stoker Co.
New York, N. Y.

JOS. J. O'BRIEN,
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Chicago, Ill.

GEORGE R. HARRISON,
Wire & Steel Mill Spec.,
Cleveland Crane & Engrg. Co.,
Wickliffe, Ohio.

JAMES S. FULTON,
Spec. Rep., Ingersoll Rand Co.,
706 Chamber of Commerce Bldg.,
Pittsburgh, Pa.

ELMER A. MULVAINE,
Chief Electrician,
The Marion Steam Shovel Co.,
Marion, Ohio.

G. D. ZUMPE,
Draftsman, National Tube Co.,
McKeesport, Pa.

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Pgh. Mgr., American Engineering Co.,
727 Oliver Bldg., Pittsburgh, Pa.

M. T. MAGUIRE,
Pgh. Dist. Mgr., Bartlett Hayward Co.,
Oliver Bldg., Pittsburgh, Pa.

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Sup. of Steam Stations,
Consolidated Gas, Electric Light and
Power Co., of Baltimore,
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J. W. JACKSON,
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168 Emmet St., Newark, N. J.

H. L. FULLERTON,
President, Industrial Electric Co.,
Westinghouse Bldg.,
Pittsburgh, Pa.

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Sec.-Treas. in Charge of Sales,
Edwin L. Wiegand Co.,
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R. W. GRAHAM,
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Bethlehem Steel Co.,
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Buffalo, N. Y.

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1321 Walnut St.,
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